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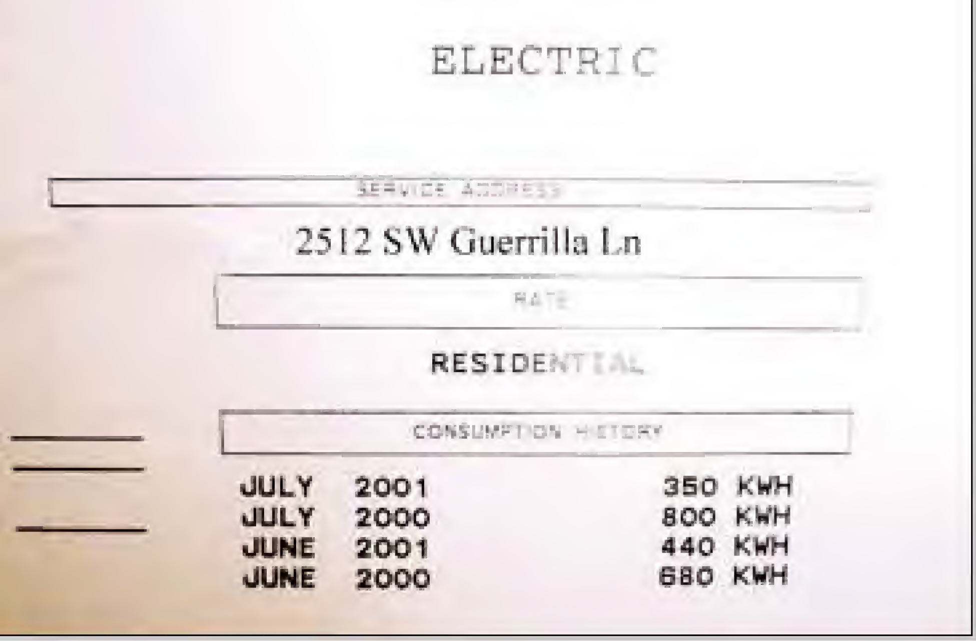

A National Net Metering Law

Oregon's U.S. Senator Gordon H. Smith invited Oregon energy people to a Renewable Energy Summit in Portland on August 8th. This meeting was to discuss what we thought Senator Smith could do to foster renewable energy. I asked him to support a federal net metering law. You can read my presentation on page 152 of this issue.

I came away from this meeting with a hopeful feeling (in spite of experiencing a utility blackout in Springfield, Oregon on the drive home). Perhaps the federal government can standardize net metering nationwide, and at the same time ensure utility compliance with such a federal law.

In the 34 states that now have net metering laws, enforcement has been a huge problem. A case in point is Mr. Kenneth Adelman of California, a state with a law allowing net metering of renewable energy systems up to one megawatt. Mr. Adelman recently attempted to interconnect his 31 KW PV system in Santa Cruz. Pacific Gas and Electric (PG&E) told him that he would have to pay over US$600,000 for a power line upgrade to handle the output of his solar-electric system.

For years Mr. Adelman has had a 200 A, 240 VAC (48 KW) utility service from PG&E. His solar-electric system is capable of producing only 31 KW, but PG&E demanded the power line upgrade anyway. When Mr. Adelman refused to pay for this bogus upgrade, and also refused to switch off his net metered PV system, PG&E terminated his utility power service—they disconnected him. Mr. Adelman is now off-grid.

For local newspaper reports on this situation, see the *San Jose Mercury News,* July 29, 2001, www0.mercurycenter.com/front/docs1/solar0730.htm, and the *Contra Costa Times,* August 4, 2001, www.contracostatimes.com/news/power/stories/sjsolarfight_20010804.htm

The glaring inconsistency here is that PG&E can deliver 48 KW to Ken Adelman's home, but claims it cannot accept 31 KW from Ken's PV system without a power line upgrade. PG&E says the power line is safe and adequate for them to sell Ken 48 KW of power, but not safe for Ken to sell them 31 KW of power. Anyone even vaguely familiar with electric power technology can see what a transparent and lame argument PG&E is making. Meanwhile, Mr. Adelman's solar contributions to the California grid are denied, just as he is being denied utility service.

Perhaps a federal net metering law—one with some teeth in it—could change these sorts of all too common situations. While we are ready to put solar energy on grid, it seems that many utilities are not willing to accept it, even if it's the law.

—Richard Perez for the *Home Power* Crew

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Solar Guerrilla 0016

"Think about it…"

I'm hopeful. I know there is a lot of ambition in Washington, obviously. But I hope the ambitious realize that they are more likely to succeed with success as opposed to failure.

—George W. Bush

PV & Wind Power Magic in Texas

David Stebbins

Twenty years ago, I was living in northern Idaho. I had a dream of living off-grid in a solar heated, solar powered home, immune to the vagaries of the world. The reality was that my wife, three toddlers, and I were living off-grid in a trailer with two 50 watt solar modules, three Sears deep-cycle batteries, a car radio for entertainment, and some tail lights for lighting. It was a pretty miserable experience.

Fast-forward to the present. I am now living in the Texas Panhandle. The kids are grown; the wife and I are divorced. I am not immune to the vagaries of the world. But I am living off-grid in a solar heated, solar powered home that I designed and built over a four year period.

Inspiration

Six years ago, I came across a copy of *Home Power* while browsing in a bookstore. Holy mackerel! A magazine written just for me! Inspired, I started to dream again. Using graph paper, I roughed out floor plans. Later I bought five acres near Amarillo, Texas, and started building.

The author with eight Uni-Solar 64 watt photovoltaic modules. Their glassless design makes for hail-proof durability.

I liked the idea of using tires and earth because the materials are free, and no power tools are needed for construction. Constructing walls from tires is labor intensive, and I had a full-time job as well. Progress was slow but steady. The only outside help I used was a neighbor with a backhoe to excavate the site, a contractor to pour the slab floor, and two (former) friends, who I supervised one afternoon while they dragged seven 300 pound (136 kg) steel I-beams around for my roof.

Rammed Earth House

The house is rectangular (22 by 72 feet; 6.7 by 22 m), with three bedrooms and two baths, and a total living area of about 1,600 square feet (148 m^2). All thirteen windows face south. The glass is double paned, low-emissivity. The total window area is more than 170 square feet (15.7 m^2). The metal roof overhangs the windows by 2 feet (0.6 m), producing shading in summer, but allowing direct sunlight penetration of about 8 feet (2.4 m) indoors in winter.

The rammed earth walls, which use tires as forms, are between 24 and 32 inches (61 and 81 cm) thick. Each course of tires is joined on each side by a 7 foot (2.1 m) long strip of tire tread, which is screwed to the treads of the earth-filled tires. The top course of tires is capped with a layer of steel reinforced concrete. The exposed tires are stuccoed over with fibrous cement—a mixture of shredded newspaper, sand, and Portland cement.

Tire house construction requires dogged determination. The image of prisoners in a chain gang breaking rocks comes to mind when I think of compacting earth in tires. The sources I used as a basis for my building method are all three volumes of Michael Reynolds' *Earthship* books and *The Tire House Book,* by Ed Paschich and Paula Hendricks. My actual building techniques varied from the recommendations in these sources, but they were a place to start.

The house is sunk into the ground about 3 feet (0.9 m). The north, east, and west walls are bermed with earth to within about 3 feet of the roof. The long north wall is reinforced with four massive, external, tire buttresses. Approximately 2,000 tires were used in the construction of the house, an attached storage building, and a retaining wall.

The insulative value of earth is poor, with an R-value of just 0.25 per inch. But because of the large mass of the wall, it is very slow to change temperature. Additionally, the house takes advantage of the moderating effects of ground temperature. At an 8 foot (1.2 m) depth, ground temperature here is approximately 60°F (15.5°C) year-round. This makes heating and cooling much easier when outside temperatures are extreme.

After two years, the shell was complete. I used 3,000 old bricks for the chimney, and for building kitchen and bathroom cabinets. Interior walls are conventional, with wooden studs and sheetrock.

Water from the Sky

The rainwater catchment system consists of two 1,500 gallon (5,700 l) tanks, a small 24 volt pump (Shurflo 2088), and a pressure tank. The annual rainfall here is 19 inches (48 cm). My daily need for water averages about 12 gallons (45 l) per day. This includes two or three loads per week in my front-loading clothes washing machine. I shower daily, and occasionally wash dishes.

The Trace TCB10 PV combiner box provides fusing for each series string of photovoltaic modules.

Since I have 3,000 gallons (11,400 1) of storage capacity, I could theoretically go 250 days without rain. I have 2,000 square feet (186 m^2) of roof. One inch (25 mm) of rain nets me about 1,000 gallons (3,800 l) of water. I get 5-gallon (19 l) containers of drinking water from town. I could drink the water from my system, but I'd do it regularly only if I had an ultraviolet system to kill bacteria. The black, aboveground, polyethylene storage tanks discourage algae growth.

Electricity

I have two separate electrical systems. My primary system uses eight solar modules, a small wind generator, twelve deep-cycle batteries, a charge controller, and an inverter. My secondary system is made up of two solar modules, a charge controller, and two batteries.

The house wiring is standard for homes of this area. I used #12/2 (3.3 mm^2) Romex wire. Inside the house, an AC mains panel feeds ten branch circuits. A couple of basic books on house wiring got me through this part of the project.

Design of the electrical generating systems was another matter. I did a load analysis using Real Goods' *Solar Living Source Book.* Perusing back issues of *Home Power,* I looked for systems comparable to the size I wanted. Similarities in the systems became evident. Using the information I gleaned from *HP* articles, I sketched out a parts and wiring diagram. The rest was easy—all you need is a credit card.

Cheap, Cheap, Cheap

Contacting *Home Power* advertisers was a pleasure. I used the Internet to search their Web sites for the lowest prices. I didn't need a full service equipment supplier, since I already knew what I wanted. All my purchases were based on price.

I ended up dealing primarily with Solar On Sale and Bargain Solar. Their prices were consistently the lowest, and they shipped promptly. They provide only limited design services, so you should know what you want when you order. As a matter of courtesy, I didn't waste the time of full-service suppliers by picking their brains, since I knew I wouldn't order from them.

PV System Design

This part of Texas is flat and has few trees. It is mostly sunny and often windy. Temperatures vary from 0°F (17.7°C) in the winter to more than 100°F (37.7°C) in the summer. Besides occasional 70 mph (31 m/s) straight-line winds, we are subject to tornados and baseball-sized hail.

I was worried about the hail, and wanted to buy the toughest PVs I could find. So I bought eight Uni-Solar 64 watt modules. These thin-film panels use no glass. They are physically larger than silicon modules of the same output, but in my case, space wasn't a problem.

Stebbins AC System Loads

Device	*Watts*	*Hrs./Day*	*WH/Day*
Computer system	528	1.50	792
Refrigerator	110	4.80	528
Microwave	1,260	0.12	151
Ceiling fans	40	2.50	100
Lights*	21	4.50	95
Circular saw	1,200	0.05	60
Washing machine	260	0.22	56
Drill	864	0.05	43
Water pump	120	0.20	24
Printer	40	0.25	10
Drain pump	1,020	0.01	8
Drill charger	20	0.33	7
		Total watt-hours per day	1,874

*19 compact fluorescents total, 21 watt average. I operate two lights at any given time (6 hours in the winter; 3 hours in the summer).

The Trace SW4024, RV Power Products SB50, and Trace DC250.

I used #10 (5 mm^2) copper wire to connect pairs of panels together in series for 24 VDC output. Two wires (a positive and a negative) were run from each of the four series pairs to a Trace TCB10 fused combiner box. From the combiner box, array output is then run to a 60 amp DC circuit breaker via 80 feet (24 m) of #2/0 (67 mm^2) copper wire.

This gives a voltage drop of 0.8 percent between the PVs and the battery bank. You always want to keep the voltage drop of your PV-to-battery wire run under 2 percent. The wire is run through PVC conduit and buried. I mounted the RV Power Products Solar Boost 50 (SB50) charge controller directly to the DC250 enclosure.

My ground-mounted racks are homemade, using 4 inch (10 cm) steel purlins, typically used in the construction of metal buildings. Metal purlins are like the metal studs used in home construction instead of 2 by 4s, only they are heavier metal. The racks are pretty simple, but rugged, and I used a fair amount of concrete to keep them anchored to the ground.

The angle of the modules is adjustable from 10 to 45 degrees. Since the panels produce ample electricity for my summertime needs, I keep them at the winter angle of 45 degrees year-round, which I hope will also make them more hail resistant. Time will tell.

Inside the SB50 and DC250.

I chose the SB50 because of a *Things That Work!* article in *HP* touting it as the greatest thing since sliced bread. It works fine, but I don't have anything to compare it to. The DC output from it runs to a shunt and 250 amp DC circuit breaker, and then to twelve Trojan L-16H batteries (1,185 AH at 24 VDC) via about 10 feet (3 m) of #4/0 (107 mm^2) welding cable. Two short lengths of #4/0 welding cable connect the shunt and circuit breaker to the inverter. The AC output of the inverter goes to a 60 amp breaker and then to the home's conventional main breaker box.

The charge controller and inverter are mounted on the wall of a 140 square foot (13 m^2) storage building that is attached to the north side of my house. Like the house, the walls of this building are made of tires filled with compacted earth. Because this building also houses my propane-fired water heater, I didn't want to put the batteries in the same space. Flooded batteries produce

A rammed earth and tire battery box.

The Southwest Windpower Air 403 on a 30 foot tall Rohn 25G tower.

explosive hydrogen gas when charging, and the water heater has an open flame; it seemed like a really bad idea to put the two close together.

To solve this dilemma, I dug a hole in the earth berm next to the storage building. I lined the walls of this hole with earth-filled tires, and capped the tires with a layer of steel-reinforced concrete. A wooden frame is anchored to the concrete, providing a frame for the doors and roof of the structure.

The doors are made of plywood, 2 by 6 lumber, and metal roofing. They are insulated to R-19 using 6 inches (15 cm) of fiberglass insulation. A 3 inch (7.6 cm) concrete floor completes the structure. It has kept my batteries dry and reasonably warm during the winter, when cold temperatures affect battery performance.

I have a Coleman 5,000 watt generator, which was used during the construction of the house, particularly during the mixing of concrete. Since installing the solar modules, I have only used it once, for 30 minutes this winter, to make sure the Trace inverter could be used as a battery charger. It worked. As a matter of pride (which goeth before a fall), I would rather reduce electrical consumption than use the genny to charge batteries.

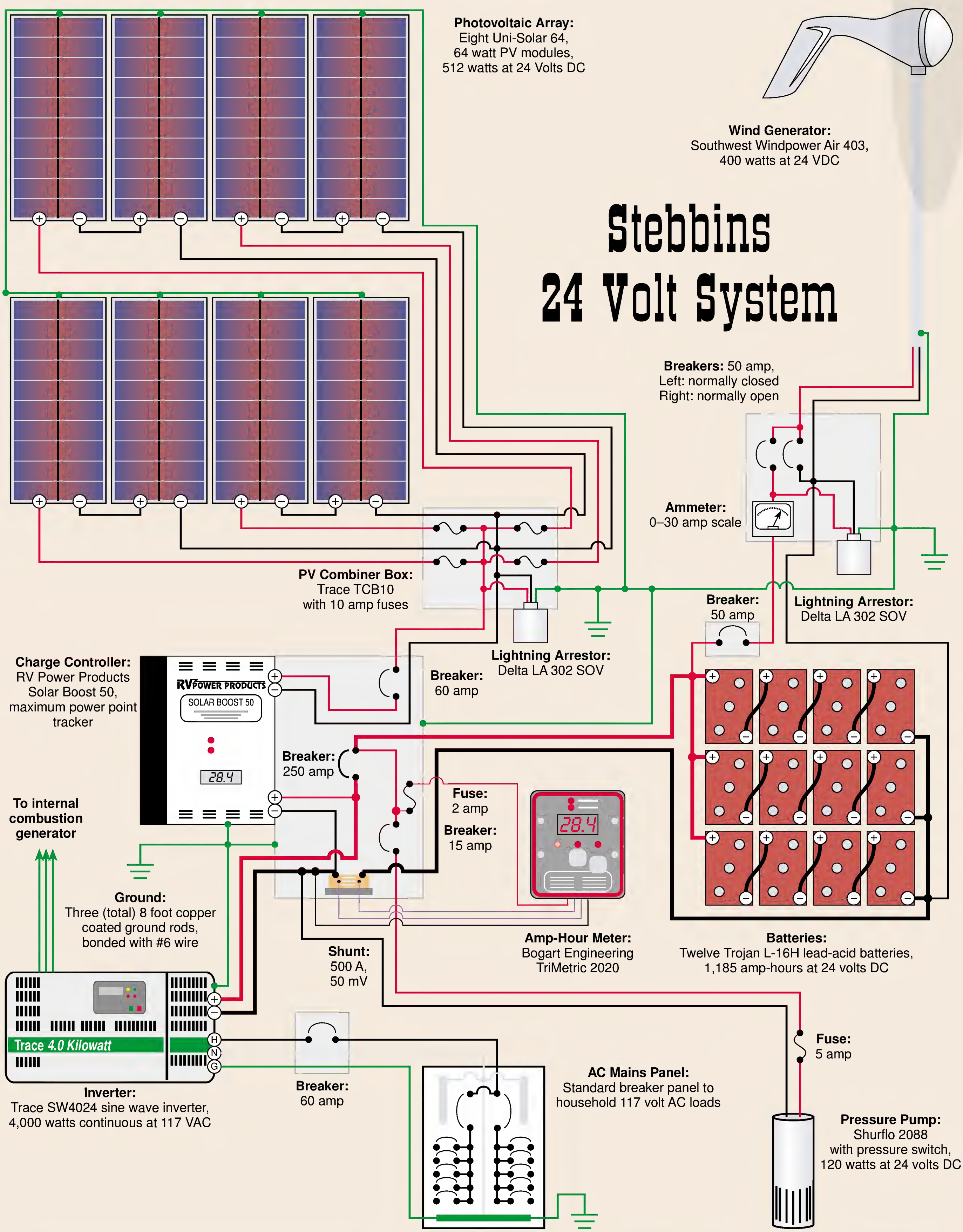
Wind Energy

My home is located on top of one of the few hills in the area. It has great wind potential. Based on a full color ad in *HP,* I contacted Bergey Windpower and ended up ordering an XL.1, their new 1,000 watt wind generator. I was told that there would be a three month wait. Three months later, I was informed that it would be another three months. I cancelled my order and got an Air 403 four days later.

The Air was easy to install. I only broke one of the blades while trying to erect it on my 30 foot (9 m) Rohn 25G tower. This was the fault of my flawed installation process. Do your homework on how to put a tower up. (See *HP23,* page 32 for an introduction to towers.) I learned the hard way, but that's another story... A week later, I received a new set of blades and finished the job.

An overcurrent breaker, a second breaker wired as a generator shutdown switch, an ammeter, and lightning protection are mounted on the tower.

Stebbins 24 Volt System



Stebbins Main System Costs

Item	Cost (US$)
8 Uni-Solar 64 watt modules	$2,280
Trace SW4024 inverter	2,250
12 Trojan L-16H batteries	1,848
Wire, battery cables, conduit	885
Air 403 wind generator	469
RV Power Products SB50 charge controller	315
Trace DC250 disconnect	237
Concrete, hardware, and miscellaneous	200
Trace TCB10 combiner box	169
Bogart TriMetric 2020 meter with shunt	169
Rohn 25G tower (30 foot, used)	120
Module racks (home-built)	116
Battery housing (home-built)	95
Fuses, circuit breakers, service boxes	84
2 Delta LA302DC lightning arrestors	68
Shurite amp meter, 0–30 amp	18
Total	$9,323

The Air is cheap, light, and cute. Because of its small rotor diameter (46 inches; 1.17 m), it doesn't produce much electricity when the wind speed is under 20 mph (9 m/s). It is noisy. Imagine a vacuum cleaner running full blast on a 30 foot tower. When the wind speed goes above about 30 mph (13 m/s), it gets even noisier. Imagine a tractor-trailer going down a steep mountain road, applying its Jake brake in a desperate attempt to slow down.

I called Southwest Windpower to find out if there was any way to make the machine quieter. They suggested lightly sanding the blades with 600 grit sandpaper and then waxing the blades with a car wax. I did this, and the Air is now a little quieter.

The energy produced by this cacophonous marvel is run down the tower through #10/2 (5 mm^2) UF copper wire in steel conduit. Two 50 amp circuit breakers and an amp meter are housed in a metal breaker box at the base of the tower. I patterned this after the box made by Applied Power Corporation. Their box is for indoor use, and I needed one for outdoor service, so I made my own.

The wind generator output goes through a 50 amp circuit breaker and to the batteries via 60 feet (18 m) of #10/2 wire in buried conduit. The Air has its own built-in charge controller, and it operates independently of the SB50. Because of the Air's "smart" controller, no diversion load is needed.

Metering, Safety, & Security

The system is monitored with a Bogart TriMetric 2020 meter, mounted discretely in an open cabinet in the living room. I monitor the battery voltage, the number of amperes actually being used by the system, and the percentage of charge in the batteries. The TriMetric has many other features, but I don't use them.

Lightning protection includes arrestors at the PVs and at the base of the wind generator tower. The system's three ground rods are all bonded together with #6 (13 mm^2) copper wire.

A 24 volt DC Shurflo water pump moves water from my storage tanks to a 36 gallon (136 l) pressure tank. I use a 15 amp circuit breaker and a 5 amp inline fuse to protect the pump wiring. The reason for the DC powered pump was to bypass the inverter. Should the inverter fail, I will still have running water.

12 VDC PV System

I needed a telephone answering machine. I didn't want to run the inverter around the clock to operate a device that draws maybe 100 mA, so I built a second, smaller 12 volt DC system. I pulled out the modules I'd bought from Backwoods Solar way back in 1981, the ones we'd used on the trailer in Idaho. I mounted them on landscape timbers (chromated copper arsenate treated... I know, I know) as skids, so I can drag them around to wherever they are needed.

These PVs are fused outdoors with a 10 amp inline fuse, and wired indoors to a small breaker box. A

These Arco and Photowatt 50 watt modules are used in the 12 volt, DC-only system.

Stebbins 12 Volt System Loads

Device	*Watts*	*Hrs./Day*	*WH/Day*
Stereo	30	7	210
Answering machine	1	24	2.4
		Total watt-hours per day	212.4

Morningstar SunSaver-10 charge controller feeds two Trojan T-105 batteries wired in series for 225 AH at 12 VDC. I operate a 12 volt answering machine and a 12 volt stereo system—really just a nice boom box. A recent lightning storm fried the circuitry of the answering machine, so I'll put a lightning arrestor on the 12 volt system, something I should have done in the first place.

The two PV systems are completely independent of each other, without any sharing of electrons between the two. The 12 volt system has only DC loads, with no inverter.

Second Thoughts

Winter heating has been a problem. Without any supplemental heat, the temperature in the house never dropped below 56°F (13°C). Unfortunately, even with the tiny wood stove cranked up for eight hours or more, the temperature never went above 67°F (19°C). The use of a Caframo Ecofan *(Home and Heart, HP76)* didn't help much. All my windows face south, and the concrete slab is insulated 8 feet (2.4 m) in from the windows with polystyrene insulation. But the earth walls stay cool all year, which is good in the summer, but not so good in the winter. I'll try a bigger woodstove with a blower this winter and see what happens.

Currently, my refrigeration needs are being met with a 4.9 cubic foot (0.13 m^3) Kenmore refrigerator, insulated on three sides with polystyrene for an additional R-15. Someday, when I'm rich and famous, I'll get a 24 volt Sun Frost.

I should have used a Solar Pathfinder to optimize orientation of the solar modules. They are off by maybe

Stebbins 12 Volt System Costs

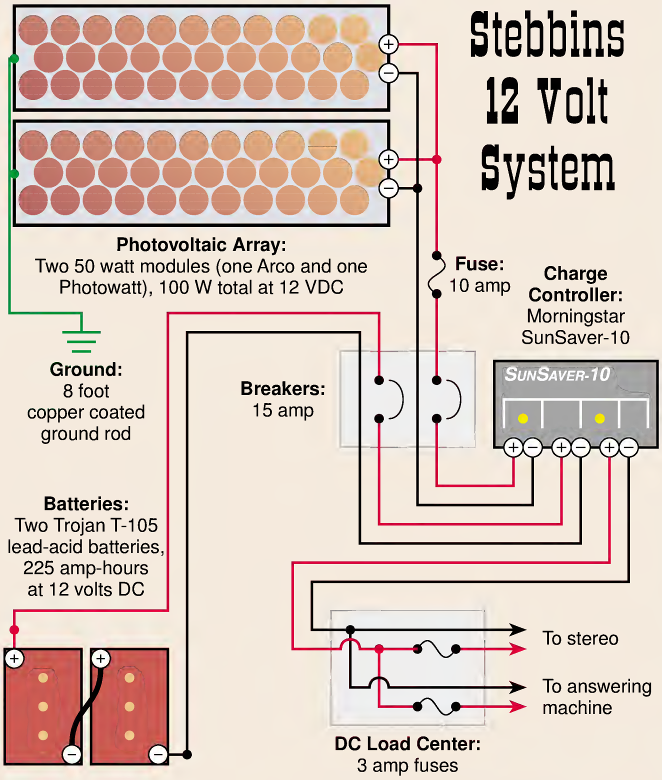
Item	*Cost (US$)*
1 Arco 50 watt module*	$400
1 Photowatt 50 watt module*	385
2 Trojan T-105 batteries	116
Morningstar SunSaver-10 controller	52
Module rack	34
Wire	24
Breaker box, breakers, and fuses	29
Ground rod	9
Total	$1,049

*1981 prices

Breakers and the Morningstar SunSaver-10 charge controller for the 12 volt system.

10 degrees, but I'm not going to change them because it's too much work.

I like my Trace inverter, but it has a search mode. With this option, the inverter remains on standby until it senses a load of 16 watts or more. In practice, I find it is more like 23 watts. Consequently, turning on a compact



fluorescent light in the bathroom at 3 AM gives the effect of a strobe light. I wish the engineering weenies at Trace would make the "switch-on" current adjustable in less than (alleged) 16 watt increments.

The Air 403 is noisy, and needs a pretty fair breeze to make an appreciable amount of electricity. A larger, quieter version of the 403 would be neat. But keep that sexy design!

At Home

I like my house. Despite the occasional frustrations, I enjoyed the design and building process. The knowledge I obtained from *Home Power* magazine was pivotal to the success of that process.

This winter, I may add four more PVs to cover myself during several days of cloudy weather with light winds. It's not practical from a cost effectiveness standpoint to think this way, but we're all allowed certain idiosyncrasies in this RE stuff. My batteries have never gone below 75 percent of capacity, and that was only one time. Mostly, they remain "Full," according to the TriMetric meter.

The electrical system is practically maintenance free. Every few months, I check the electrolyte levels in the batteries. Every six weeks, the batteries get an equalization charge, which involves my having to push a button on the charge controller. When it snows, I get a broom and sweep off the solar modules.

I enjoy living in the house. On sunny days, I disconnect the wind generator, since the PVs completely charge the batteries by noon. I run lights, computer, microwave, tools, small appliances, washing machine, and stereo. The system would operate a television if I wanted to watch one, but I don't. Using sun power to play my favorite CDs always gives me a thrill.

Friends ask, "How do you like your new house?" My response is, "It's getting used to me." The house uses natural forces for my comfort. Directly or indirectly, the sun, wind, and rain provide me with heating, cooling, water, light, refrigeration, and even music. I have become more attuned to the various forces involved. When the sun shines, I know I have ample electricity. When the wind blows, I know I'll get more electricity. When it rains, I know the parched earth is getting renewed, and my water tanks are being filled.

Access

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Earthship: How to Build Your Own, Earthship: Systems and Components, and *Earthship: Evolution Beyond Economics* (volumes I, II, and III), Michael Reynolds, $29.95 each postpaid, Solar Survival Press, PO Box 1041, Taos, NM 87571 • 505-751-0462
Fax: 505-751-1005 • biotecture@earthship.org
www.earthship.org

The Tire House Book, Ed Paschich and Paula Hendricks, 96 pages, ISBN 0-86534-215-6, US$14.95, Sunstone Press, PO Box 2321, Santa Fe, NM, 87504
800-243-5644 or 505-988-4418 • Fax: 505-988-1025
www.sunstonepress.com

The Solar Electric Independent Home Book, 1998, ISBN 1-879523-01-9, 180 pages, US$16.95 plus US$3 shipping from New England Solar Electric, PO Box 435, Worthington, MA 01098 • 800-914-4131
or 413-238-5974 • Fax: 413-238-0203
nesolar@newenglandsolar.com
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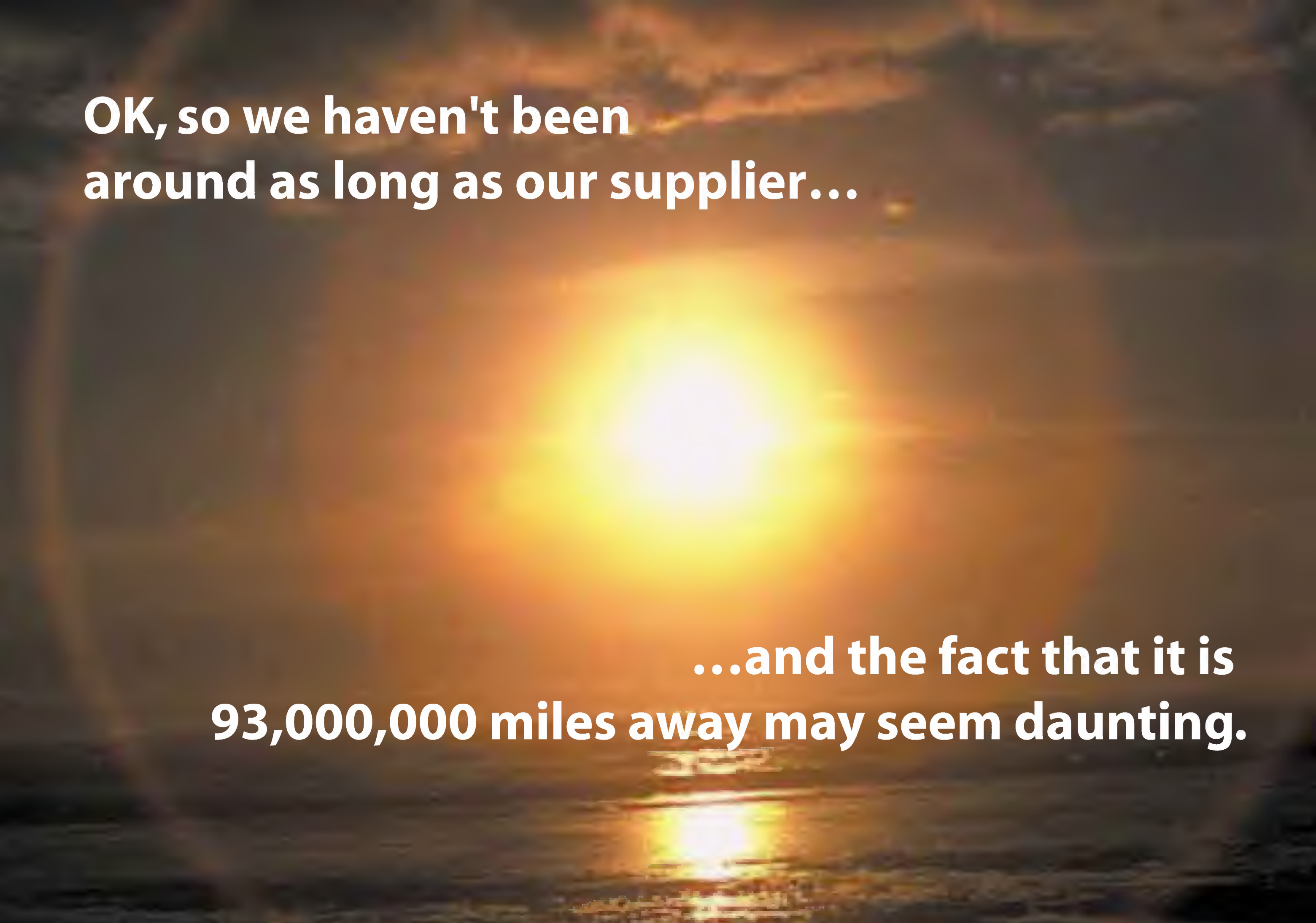

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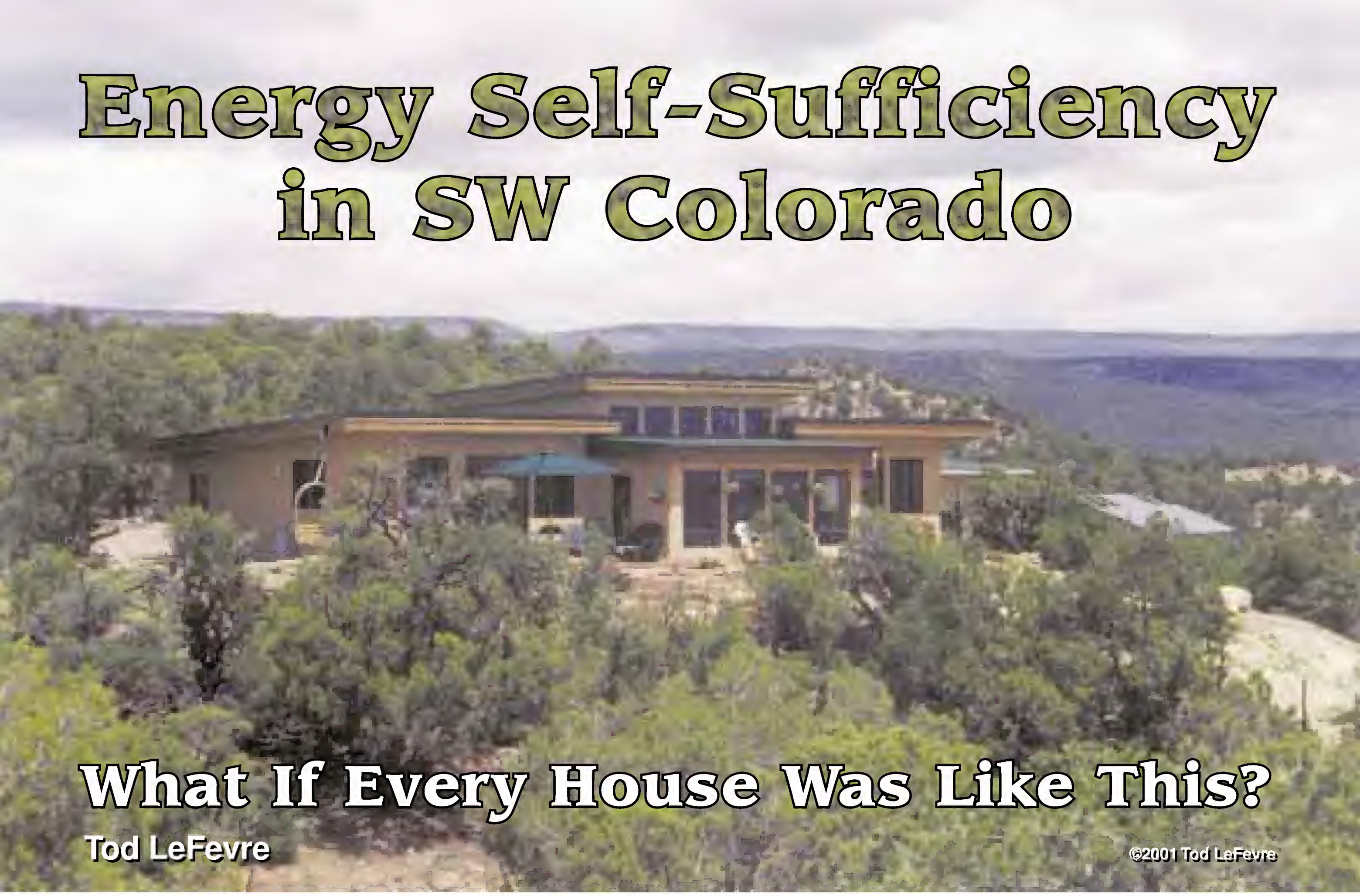


What If Every House Was Like This?

Tod LeFevre

©2001 Tod LeFevre

The LeFevre solar powered, high efficiency home is built with straw bales and other natural materials.

The question is always, "What got you started on this solar stuff?" Well for me, it was when I built a solar hot dog cooker for a sixth grade science project. From that point on, I was enthralled with the power of the sun.

As my life progressed, I always had a set of house plans for a completely self-sufficient dwelling, and was just waiting for the right time. My wife and I found a great piece of property in southwestern Colorado in 1995, and it has forever changed our lives. We spent a year in the study and design phase, which we both feel is the most important step. Then we dove into construction, working full-time jobs as well. After four years without looking up, we could finally sit on the deck and say it was worth it.

Solar Straw Bale Home

Our home is a 2,000 square foot (186 m^2) straw bale, passively heated and cooled structure. About 90 percent of our winter heat is provided by having south-facing windows and a colored concrete floor for the sun to shine on. This warms the high thermal mass slab, and the super insulation of straw holds the heat in. We stay cool in the summer by having properly sized roof eaves to keep the sun out, the concrete floor to maintain a constant temperature, and the insulation value of straw.

Electricity is supplied by a solar-electric system. The sun creates DC electricity through photovoltaic (PV) panels on a tracker, and the energy is stored in a large battery bank. An inverter changes the DC to AC power, which runs the conventional appliances of the house.

Hot water is produced by solar hot water panels on the roof, and stored in a tank in the utility room for everyday use. Domestic water is collected from the roofs of both the shop and house, filtered, and stored.

Since water is such a valuable resource, all greywater from the sinks, showers, and laundry is filtered and run through the sunroom planter bed to water various plants. The toilets are composters, using no water, just the natural biological degradation that has worked on this planet since life began. The finished compost looks like peat moss, and can be used as garden fertilizer. This house is almost entirely self-sufficient. The only necessary outside energy source is a small amount of propane.

Architecture & Design

To design this house, we asked years' worth of questions and drew answers from realistic and logical conclusions. Our major architectural influences were Charles Woods and Malcolm Wells, who have written numerous books on energy efficient building design. Their standards, combined with some Southwestern style, while keeping total function in mind, led to the final outcome. We wanted the house structure to blend into the natural surroundings and be easy on the eye.

Southern view of the house showing the sunroom, which acts as a double envelope for the living space.

To start off construction, we built a 1,200 square foot (111 m^2) shop, using the same energy efficient principles as the house. This gave us a building to house the solar-electric system, water supply, and construction tools necessary to start the house project. This was an invaluable step because it allowed us to test passive solar design principles and construction methods.

The ideal house site on our property, to maximize the view, was a rocky knob of Dakota sandstone. We had wanted to build back into a hillside, but we opted for the view instead, which left us perched on top of a desert mesa. A single story structure was used to minimize exposure and provide wheelchair access if necessary.

A simple rectangular design with a practical shed roof kept our building costs low. We made the eaves overhang 4 feet (1.2 m) to increase water collection area and protect the straw walls. This was combined with an 18 inch (46 cm) wide fascia to give the exterior a bold look. From the photos of the southern elevations, you can see how we tried to match the exterior colors of the house to the natural surroundings, and blend into the desert environment. From a distance, it is difficult to distinguish the house from the cap rock of the mesa.

Outside landscaping was designed to make the transition between what we disturbed and the natural ground as subtle as possible, using native rock and vegetation. Outside lights face down to emphasize the structure, and so they don't shine in our eyes.

The exterior blends into the interior with the same floor surface and similar wall colors. On a mild weather day, the usable square footage of the house doubles when we open the French doors of the great room and master bedroom. All interior rooms were laid out with the emphasis on usable space. No hallways or other space-wasting areas were included.

All rooms are naturally lighted by careful placement of exterior windows, interior doors with windows, and transom windows above. The elevated section, or roof monitor area of the house, was designed with clerestory windows to let winter sunlight into the living area. This allows for natural heat recirculation with a whole-house fan system, and vents unwanted heat in the summer.

The kitchen, which is open to dining and living rooms, helps with solar gain.

The master bedroom is light and warm due to solar gain and thermal mass.

South-facing glazing was designed and built at 12.2 percent of total interior square footage. The sunroom has 34 percent southern glazing, with a sliding glass door to isolate it from the house during certain times of the day, depending on the season. East, west, and north windows were kept below 4 percent total square footage to minimize winter heat loss.

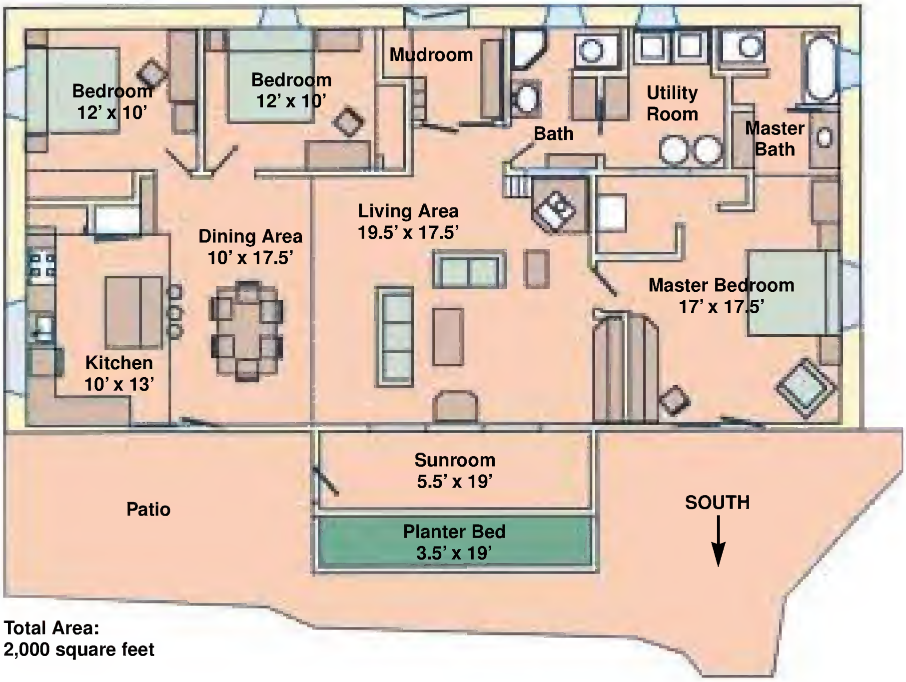
The roof eaves were designed to allow the proper amount of winter sun in, while keeping the summer sun out. Because glazing is a very important issue in a passively heated and cooled structure, south-facing windows are double pane with a low-E hardcoat on surface #3 (the outer surface of the inner pane). This allows the greatest amount of solar gain in, while decreasing U-values to meet many current building codes. All east, west, and north windows are double pane, low-E. This reduces undesirable morning and evening overheating, and decreases U-values on the sides of a structure where there is a net energy loss.

Passive Solar Design

The house is a simple rectangle, 30 by 60 feet (9 by 18 m), with its long axis running east-west. A 10 by 20 foot (3 by 6 m) sunroom is attached on the south side. Insulation consists of the east, west, and north walls of straw, while the south wall is 2 by 6 inch stick-frame. The straw walls have an assumed R-value of at least 45, and the stick-framed wall has additional insulation on both sides, bringing the R-value up to 32. The roof has an R-value of 55, with a layering of several insulation types.

Interior thermal mass consists of an 18 by 60 foot (5.4 by 18 m), 6 inch (15 cm) concrete slab on the south side of the structure. Additional mass comes from 2 inch (5 cm) thick concrete and gypsum plaster on the inside of the straw walls, and 5/8 inch (16 mm) drywall and gypsum plaster on the stick-frame walls. In the sunroom, a 3 by 20 foot (0.9 by 6 m) planter bed gets direct sunshine from September 1st through May 1st, adding enormous amounts of moist heat.

LeFevre Floorplan



Total Area:
2,000 square feet

With winter local heating degree days at approximately 6,500, the auxiliary heat performance level was calculated at 14,404 BTUs per year, per square foot. (We found *Passive Solar Design Strategies,* listed in Access, very useful for making these calculations.) The actual maximum temperature swing is 8.8°F (4.9°C). On the practical side, it only took half a cord of construction scraps to keep the house a comfortable 70°F (21°C) all winter. The coldest the house ever became during an extended leave was 63°F (17°C), with outside

A garden bed stretches the length of the sunroom.

temperatures down to less than 5°F (-15°C). With local summer average high temperatures greater than 90°F (32°C), the actual high temperature for the house was 72°F (22°C) during the construction summer of 1999 and only 70°F (21°C) last summer.

Ventilation

The house was designed to provide easy internal movement of air with ceiling fans in central rooms. A whole-house, 24 VDC fan also moves air at less than 5 feet per second throughout the back rooms, and ventilates the front of the house through the transom windows. The composting toilets also have 24 VDC fans continuously exhausting to create a gentle vacuum in the tightly constructed structure.

We installed four "earth tubes" around the house. Each tube is 100 feet (30 m) of 4 inch (10 cm) PVC buried around the foundation. The intakes are located under the eave of the roof, and the other ends are in specific areas of the house. These tubes allow the gentle vacuum of the house to suck in outside air that is cooled in the summer or heated in the winter by natural ground thermodynamics. They provide a fresh air exchange every 2.5 hours. This is one of the greatest attributes of the house. We can leave for a month with all the windows closed, and when we return, the house is full of fresh air.

Electricity

Our plans included eventually having a family, so the power system was designed for expansion. Both the current setup and what is planned for the future will provide electricity through a three-day, winter storm cycle. After that, we have the propane generator as backup. We got the system up and running as soon as possible during construction, so we could shut the stinking generator off.

The system provided all the power for the house construction project. At one point during a framing weekend, we had fifteen people working. That included one table saw running almost continuously, two compound miter saws, and at least three circular saws. We were very blessed with Colorado cloud-free, blue skies, and ran the generator for only a few hours during the whole weekend.

Fourteen (of a possible eighteen) Siemens SP75 photovoltaic modules provide 1,050 watts of power.

The Ananda Power Center and Trace SW4024 came prewired and were bought used.

Inside the Ananda Power Center you can see the main pullout DC disconnect, DC breakers, and the backs of the TriMetric and Smart Charger.

The initial system included a Wattsun eighteen-panel tracker with fourteen Siemens SP75 panels on it. Our plan was to add two panels per child—do you think they will understand that those two panels will only produce 825 watt-hours per day of juice in the winter?

The tracker is located with unobstructed, sunrise-to-sunset access to get full use of the available sun. In the summer, we generally turn the tracker off and leave the rack aimed at high noon, since we have a surplus of energy then. In the winter, I believe it really pays to get every minute of sun. During storm cycles, the sun only shines from 7 to 10 AM, but those three hours are enough to keep all those extra winter loads running.

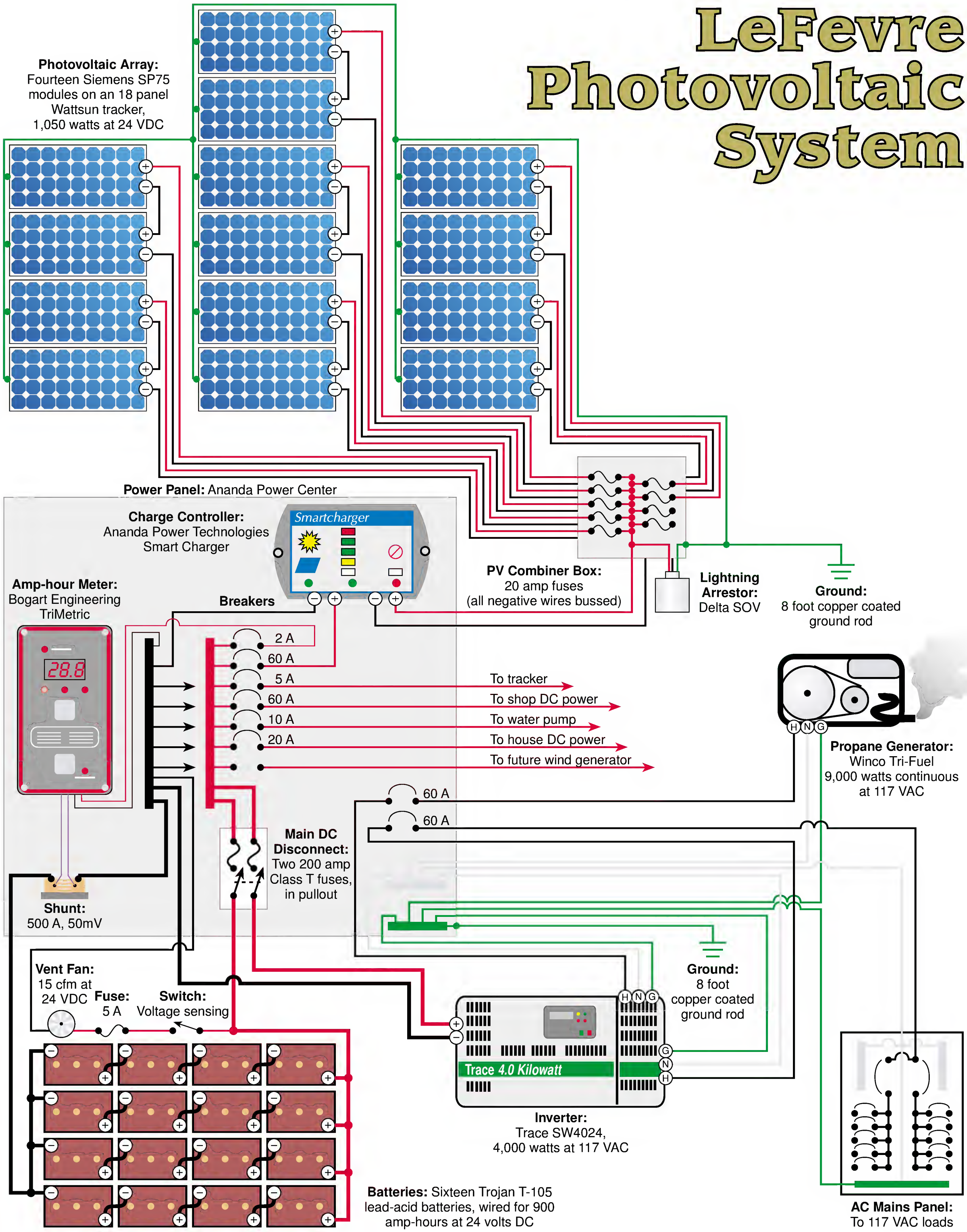
The heart of the system is a used Ananda Power Center and a Trace SW4024 inverter. Power centers are worth every penny to a self-installer like me. The manuals were fantastic, and everything was already labeled. Buying a used inverter and power center saved some cash, but the big advantage was that the power center was prewired. The TriMetric meter has proved very useful. During the winter months, we have to be careful with our energy usage, and the meter tells the story.

The power center, inverter, batteries, and generator are located in the water storage room of the shop building. I put them all together so the mass of the water could keep the batteries warm during the winter. We also installed a digital volt meter in the utility room of the

LeFevre Solar-Electric System Costs (1997)

Item	*Cost (US$)*
14 Siemens SP75 panels	$4,480
Used Ananda Power Center, Trace SW4024 inverter, & TriMetric meter	3,400
Winco 9,000 watt, tri-fuel generator	2,120
Wattsun 18 panel, dual-axis tracker	1,875
16 Trojan T-105 golf cart batteries	960
Misc. supplies, conduit, poles, wire, etc.	375
3 Delta lightning arrestors	185
Combiner box for tracker	55
Total	$13,450

LeFevre Photovoltaic System



Twelve of the sixteen Trojan T-105 lead-acid batteries that provide 880 amp-hours of storage.

house. My wife Marti can just look at it, and based on minimum set voltages, she knows when she can do various domestic chores. If the sun is shining, almost anything is legal.

The current battery bank has sixteen Trojan T-105s (900 AH at 24 VDC). The future bank will have sixteen L-16s (1,400 AH at 24 VDC), so the kids can experience a modern childhood.

Water

Water is provided by rainwater collection off two shed roofs totaling 4,608 square feet (428 m^2). With an average annual rainfall of 12 inches (30 cm), we'll get 34,560 gallons (130,820 l) of water. That means we don't have any water to spare, but there will be enough to run a household. Assuming a 2 percent loss for the roof washing system and other losses, that's almost 34,000 gallons (128,700 l) of water per year, or about 93 gallons (350 l) per day for the household.

The first 3 gallons (11 l) of each rainfall are discarded to get rid of anything that might have blown onto the roof. I got this idea from the book, *Rain Water Collection for the Mechanically Challenged.* The authors discussed the need to discard that first rush of water, and I adapted their idea so I could use local plumbing supplies.

The flow is then directed through a 5 micron bag filter to remove any of the medium-size particles. Our water tanks are made out of black food-grade plastic, which is safe for drinking water. They are enclosed in an over-insulated, aboveground room, with minimum natural daylight. The dark, cool environment reduces algae and bacteria growth.

The water is of excellent quality, similar to store bought bottled water. The only water treatment we are currently employing is a UV light filter to kill any possible bacteria that could grow in the storage tanks. We have designed 9,500 gallons (36,000 l) of storage, which should last

LeFevre System Loads

Load	*Watts*	*Hours per week*	*Average WH per day*
Shop tools	1,200	5	857
Sun Frost RF-16 refrigerator, 24 VDC	35	168	840
VestFrost chest freezer, 7.5 cf	25	168	600
TV and stereo system	150	28	600
Miscellaneous	1,000	4	571
2 RCH ceiling fans, 24 VDC	40	84	480
4 House and shop lights, 20 watt	80	28	320
Hot air recirculation fan, 16 in., 12 VDC	20	84	240
2 Sun-Mar composting toilet fans, 12 VDC	10	168	240
Asko dishwasher (2 loads per week)	700	2	200
Staber washing machine	250	4	143
2 El-Sid DHW and in-floor heating pumps	10	84	120
Laptop computer and ink jet printer	55	12	94
Microwave	1,200	0.5	86
Blender	350	1	50
Rain water pressure pump, 24 VDC	60	4	34
		Total average watt-hours per day	5,476

The Winco 9,000 watt backup generator runs on propane.

An Aquastar BS on-demand water heater (upper left) backs up the solar hot water system.

through a three-month dry spell. Looking back at precipitation data from a 25 year local history, we would only have had to haul water during four extended periods of drought.

Domestic hot water is supplied by a used active solar hot water system. It is very easy to find good used equipment in any large city. The system I purchased was about fifteen years old, and had never had water in it. It had spent some time on a roof, but the owner had never primed it. It consisted of three, 4 by 10 foot (1.2 by 3 m) panels and a 120 gallon (450 l) heat exchanger tank. It had a simple two-temperature controller to operate the 24 VDC pump that circulates the propylene glycol.

The 120 gallon heat exchanger tank is plumbed to an Aquastar BS on-demand water heater in case we run out of solar hot water. It hasn't really been necessary, but I wanted it in case guests needed it. The roof heat collection system is oversized for the storage capacity, so it can provide additional heat in the winter to the in-floor heating system. In the summer, one or two panels need to be covered, depending on use.

All of our appliances are the most efficient models available. The Asko dishwasher uses 4.6 gallons (17 l) per load, and the Staber washing machine uses 16 to 22 gallons (60 to 83 l) per load. All sinks and showers have water-saving fixtures as well.

The kitchen sink has an on-demand hot water system to eliminate wasting water while waiting for it to get warm. A Metlund, D'mand circulation pump is activated by a switch at the kitchen sink. The pump runs for a minute, circulating water from the hot water tank and back through the cold line, until a temperature switch turns the pump off. Then you have hot water 50 feet (15 m) away from the solar hot water tank, without wasting any of that precious rainwater, while using very little energy.

Greywater & Composting Toilets

Greywater is collected from the showers, bathroom sinks, and the washing machine. It drains through a 3 by 20 foot (0.9 by 6 m) planter bed in the sunroom. A year-round garden is maintained using this recycled greywater. We have had good luck with tomatoes, herbs, flowers, and other aboveground vegetables. The kitchen sink greywater is decanted off into a small plastic tank, and piped to an outside flower and shrub garden.

Sun-Mar's nonelectric Excel composting toilets were chosen for their long track record. They use no water and only 10 watt-hours of electricity per day to run the fans. They have proven themselves, and we would consider them even in a more conventional home. The toilets' fans exhaust bad odors immediately.

Materials

All wood products were specifically selected from the local sawmill, which is about 40 miles (65 km) away. Particle board was selected for its use of 50 percent Aspen wood, and because it is produced at a local mill, about 90 miles (145 km) away. All interior wood was

Mexican tile adds natural beauty to the earthy decor.

sealed with oil-based, nontoxic stains. Concrete stucco was used for its longevity and minimal maintenance. We also decided to use a colored concrete floor instead of an adobe floor because of its better thermodynamic properties and lower maintenance.

Naturally colored stucco and plaster were selected from local manufacturers. Green and earth friendly materials were always chosen first if available. But with some construction materials, like insulation, we had a hard time finding alternatives to fiberglass and foam. We tried to locate cotton insulation, but the manufacturer had gone out of business. Solar gain, insulation, and thermal mass are the basis of an energy efficient home.

Custom Features

Many custom features in our house may not be evident in the photos. The windowsills in the straw walls are 24 inches (61 cm) deep, finished with authentic Mexican tile. All the sills are done differently, depending on the decor of the room. Marti did a stained glass picture over the entryway, with a local mountain scene. *Nichos*, or small cubbyholes, are set into the straw walls of the bathrooms and bedrooms for use as handy shelves, which are also finished with Mexican tile.

The entertainment center is made from re-sawn, recycled Douglas fir beams that were discarded as scrap after completion of the roof. The dining room table, two end tables, and one guest bed frame were made out of leftover lumber from the house. All the rock for the exterior landscaping came from the house excavation or from our land.

Self-Sufficient

My wife and I always wanted to build a house that was completely self-sufficient, or as energy efficient as practical. After we found the land, it took five years of planning and hard work to make it a reality.

We are very excited with the result of our extensive research and hard labor to create a nearly self-sufficient dwelling. The only outside energy necessary is propane for the kitchen range, backup water heater, and generator. That brought our first year's total utility bill to US$62.

After a year of living in this beautiful house, we feel that its greatest attribute is the warm and comfortable living environment that can be generated by such an energy efficient structure. We are so pleased with the finished product that if we do it again, we will change very little.

This home was built without compromising any known energy efficiency principles. We created a low environmental impact dwelling that allows its occupants to live a very comfortable and conventional lifestyle. We thank everyone who helped and supported us to build such a beautiful residence.

We only were able to live in our dream house for a year because of unforeseen circumstances. I had to move to sea level because of a heart/lung condition. I'm 37 years old and was running marathons a few years ago, but I had a heart defect that caused a chronic lung condition.

We hated to leave Colorado and the house we spent five years building, but there isn't much quality of life if you can't breathe. We built the house to raise kids and live a lifetime in, but the Big Guy had another plan for us. We are happy and thankful for the lovely couple who purchased the property and plan to retire there.

Access

Tod LeFevre, P.E., PO Box 231, Kinstown, St. Vincent, West Indies • 784-457-5837 • tjlefevre@aol.com

Abraham Solar, Mick Abraham, 124 Creekside Pl., Pagosa Springs, CO 81147 • 800-222-7242
Phone/Fax: 970-731-4675 • all solar-electric equipment, Sun Frost, Staber, house fans, water pumps

Atlasta Solar, 2923 North Ave., Suite 8A, Grand Junction, CO 81504 • 970-248-0057
Fax: 970-248-0094 • atlasta@gj.net • solar hot water & in-floor heating equipment

Architerra Enterprises, Inc., 0186 SCR 1400 BRR, Silverthorne, CO 80498 • Phone/Fax: 800-563-9720 or 970-262-6727 • natural@colorado.net
www.thenaturalhome.com • design consultation, composting toilets, & greywater system

ACT Inc., Metlund Systems, 3176 Pullman St., Suite 119, Costa Mesa, CA 92626 • 800-METLUND or 714-668-1200 • Fax: 714-668-1927 • info@metlund.com
www.gothotwater.com • S-01 D'mand standard model hot water demand system

Passive Solar Design Strategies: Guidelines for Home Building, 1990, 85 pages plus software and guide, US$50, Sustainable Building Industry Council (SBIC),1331 H St., NW, Ste. 1000, Washington, DC 20005 • 202-628-7400 • Fax: 202-393-5043
sbic@sbicouncil.org • www.sbicouncil.org

Designing Your Natural House, 1992, Charles Woods & Malcolm Wells, Van Nostrand Reinhold, ISBN 0-442-01327-2, 243 pages • presently out of print, but check used booksellers

Other books by Malcolm Wells are available from Underground Art Gallery, PO Box 1149, Brewster, MA 02631

A Natural System of House Design: An Architect's Way, 1997, Charles Woods, 219 pages, ISBN 0-070-71736-2, The McGraw-Hill Company.

Other books by Charles Woods are available from Charles Woods & Associates, Architects, 65 Commercial St., Honesdale, PA 18431

Climatic Building Design, 1983 and 1993 pbk. reprint ed., Donald Watson & Kenneth Labs, 288 pages, The McGraw-Hill Company • out of print, but check used booksellers

Rainwater Collection for the Mechanically Challenged, Suzy Banks with Richard Heinichen, 46 pages, ISBN 0-9664170-0-3, US$15, Tanktown, PO Box 1541, Dripping Springs, TX 78620 • 512-894-0861 Fax: 512-858-2321 • tanktown@aol.com www.rainwatercollection.com

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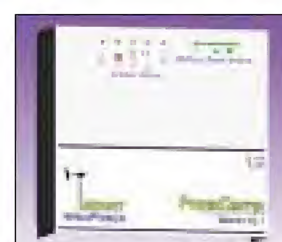

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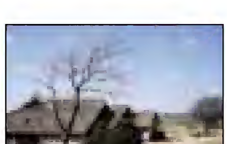
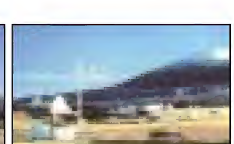


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GUERRILLA ON THE GO!

GUERRILLA SOLAR: The unauthorized placement of renewable energy on a utility grid.

PROFILE: 0016

DATE: August, 2001
LOCATION: Classified
INSTALLER NAME: Classified
OWNER NAME: Classified
INTERTIED UTILITY: Classified
SYSTEM SIZE: 600 watts of PV, 400 watts of wind
TIME IN SERVICE: 6 months
PERCENT ANNUAL LOAD: 10 to 15 percent

I have always been interested in solar energy and other renewable energy sources. I bought my first solar panel in 1987, and that just started a long-term addiction. I now live in an apartment complex where I'm not able to permanently mount anything—my landlord would have a fit. So my guerrilla solar setup had to be made as portable as possible.

My system consists of six Photowatt PW 1000, 100 watt panels, an Air 403 marine wind generator, a Solar Boost 50 (SB50) charge controller, a Trace PS2512 inverter, and eight GNB deep-cycle, gel-cell batteries rated at about 100 amp-hours each. Generally I only wire four of the batteries up to my inverter at a time. Right now, I have my wiring fused for safety, but I'll eventually install circuit breaker protection to keep my rig safe. While the system I have here isn't exactly what I would consider my "dream machine," I got deals that I just couldn't refuse on several of the products, so I designed the system to work with this gear.

Everything has to be portable, since I have to be able to move it around often. So I decided to make the system as modular as possible. The Photowatt PW 1000 PVs are field configurable for either 12 or 24 VDC. I wired each module for 24 VDC, and use the SB50 to drop the voltage down to 12 VDC to charge the batteries. The 24 VDC PV output lets me use smaller wire between the PVs and the batteries, because I'm only moving half as many amps compared to a 12 VDC PV output.

The panels often have to be put away at night, or on a certain day of the week when the maintenance crew for the apartment complex comes through to mow the lawns. I didn't want to have to open up the junction boxes every time I had to disconnect. So I took some good outdoor #12/3 (3.3 mm^2) extension cord wire, and wired about 6 feet (1.8 m) to each panel.

Since the plugs are normally polarized to begin with, I used that to my advantage. I paid attention to the polarity of the panels as I wired the plugs up, and since the plugs can only be connected one way, the polarity is always correct. Each of the panels has a plug on it, and I have two heavy duty three-way extension plugs. Three panels plug into one extension pigtail, and three plug into the other one.

Short circuit current on my panels is rated at 3 amps each at 24 VDC, for 9 amps total for a three-panel subarray. Because the pigtail connectors are only about a foot (30 cm) long, the voltage drop is negligible. Each of the two pigtails plug into a standard receptacle. But since this is the main 24 volt bus running between the PVs and the charge controller, I decided to use about 30 feet (9 m) of #2 (33 mm^2) wire for that run to minimize any line losses due to the long run. [*Editor's note: The PV to charge controller wiring in this system is not rated for DC applications. Make sure to use DC rated equipment when you install your system.*]

Inverter, Batteries, & Metering

The inverter is a Trace PS2512 inverter. Originally I wanted to go with 24 volts (a Trace SW unit) to cut down on line losses and cost, but I found this PS2512 that someone was selling because it made too much noise. I got the inverter, a conduit box for it, and the remote unit for programming it for US$1,100.

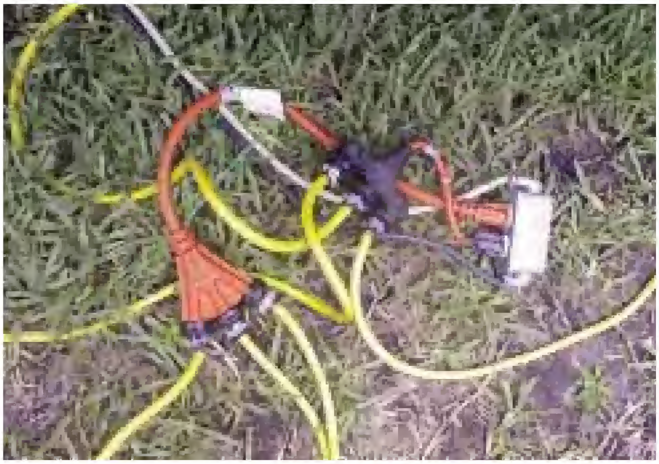
The batteries are government surplus. They came from an old uninterruptible power supply (UPS) system, and I know for a fact that they were never discharged hard, and were only about a year old. The batteries are manufactured by GNB and are the "Sprinter" series. As a test of their capacity, I have discharged them at a rate of 15 to 20 amps each, selling them down to 10.9 volts. Each one put almost 600 watt-hours into the grid. The batteries are totally sealed, with a float voltage of 13.5 to 13.8 volts.

I use a Brand Electronics 20-1850 digital power meter for the AC side of the system to keep track of how much I am putting back into the grid. This is a nice little unit at a very good price. I have only had one problem with the meter in the five years I've owned it. I sent it back to the manufacturer, and it was taken care of immediately.

Wiring Details

The entire inverter/battery/metering setup is located in my laundry room. Since I don't have a washer or dryer, I can conveniently run the DC cables in from the PVs through the unused dryer vent. And I also have a very accessible receptacle to hook to the 115 VAC. I only really needed about 10 feet (3 m) of cable to reach my equipment. I put the extra 20 feet (6 m) on there in case I have to move the panels elsewhere, and for when I decide to take them on the go with me.

Once the wires from the PVs enter the Solar Boost 50, I have it configured to drop the voltage down to 12 volts for the battery bank, and to feed the inverter. Since I am using the inverter primarily to sell back to the grid, I didn't foresee having to pump any great power through it, so I fused the battery bank at 125 amps. This is more than sufficient for all the power I could ever generate. When I do grow the system, I can upgrade the fusing. The wire I used for battery interconnection and connection to the inverter is #4/0 (107 mm^2) heavy duty, 133 percent, marine grade cabling. Again, I left plenty of room for expansion.



Plug'n'play portability allows this system to travel easily.

Loads & Production

Besides the basic loads such as the refrigerator, lights, etc., I have a computer that runs 24/7, and three heat lamps at 220 watts overall that run all the time for my reptiles. These lamps alone are a real killer at almost 160 KWH a month. Without the lights for these pets, my system would cover about 50 percent of my electricity. The biggest way to save money has always been conservation—turn off the lights when you leave the room, kill the phantom loads, etc. But sometimes you are not able to do that.

I can average a good 75 to 100 KWH with my panel output in a decent month without too much rain. I can also get some good short term, high yield storms running through for wind power. I have found that my utility bill is a *lot* lower than it was before I put my system in. This is due to my system output, combined with a new awareness of my energy usage.

Being in the Southeast, in one of the warmer climates in the U.S., the panels do tend to take on some heat, which reduces their performance a bit. I have them on portable benches to help air flow around them for cooling, but when it's a hot, muggy, breezeless day, they don't produce quite what they are rated at.

On a sunny May day, I can still pump a good 2.5 to almost 3.0 KWH into the grid. During the summer months I have another hour or more of sunlight to use, and I can get an easy 3 KWH plus a day from sun power alone.

Portable Guerrilla System Costs

Item	*Cost (US$)*
6 Photowatt PW 1000 PV panels, 100 W	$2,430
Trace PS2512 inverter	1,100
1 Air 403 marine wind generator	600
1 Solar Boost 50 charge controller	300
Miscellaneous hardware	200
Shipping & handling	150
8 GNB deep-cycle, gel-cell batteries	80
Total	$4,860

When I am home to play with my setup, I rotate the panels one way to catch a few extra amps from the morning sun. In the high noon sun, I aim them straight south, and later I turn them to the west to catch the extra amps from the evening sun. If I am not home, I just leave the panels pointing straight south for an overall average.

This portable system might seem like a pain to lug around, but it's actually very easy. I can go from nothing to totally operational in about ten minutes, and have it packed up and put away in the same amount of time. If I am going out of town for a few days, I can haul the panels and the SB50 in the back of my truck, set them up wherever I'm going, and charge up the batteries. Then I use the inverter to sell them down when I get back home.

Wind Guerrilla

The wind part of my setup is another adventure in creative construction. The corner of my apartment building makes sort of a wind tunnel. I can't put up a 30 foot (9 m) tower (again, the angry landlord thing). Instead, I've taken a 10 foot (3 m) piece of pipe and U-bolted it to the fence, which is sturdily mounted to the side of the building.

When I see a storm coming on, or when we are having one of our windy days, I simply mount the generator on top of the pipe, tilt it up, drop the end through the U-bolt rig, and tighten it down for stability. Once it's sturdy, I switch the generator on and let it spin. Again, I needed portability, so I used the same #2 (33 mm^2) wiring running up the pipe, but the ends are welding-type twist connectors rated at 100 amps.

I go a little crazy with my portable wind power system. I work at a Navy base that is very close to the ocean. There are days when we have quite strong winds coming off the ocean all day long. I'm talking 15 to 25 mph (6.6 to 11 m/s). So my truck is sitting in the parking lot getting sandblasted. I might as well *use* that wind for my benefit.

On the back of the truck, I have a 1/2 inch (13 mm) steel plate that bolts to the bumper step. On this plate I've welded a 2 inch (5 cm) ID piece of steel pipe about 18 inches (46 cm) long. I take the 1-7/8 inch (4.76 cm) OD pipe that I mount the wind generator on, and just drop it into the bolted-on pipe sleeve and I'm set to go.

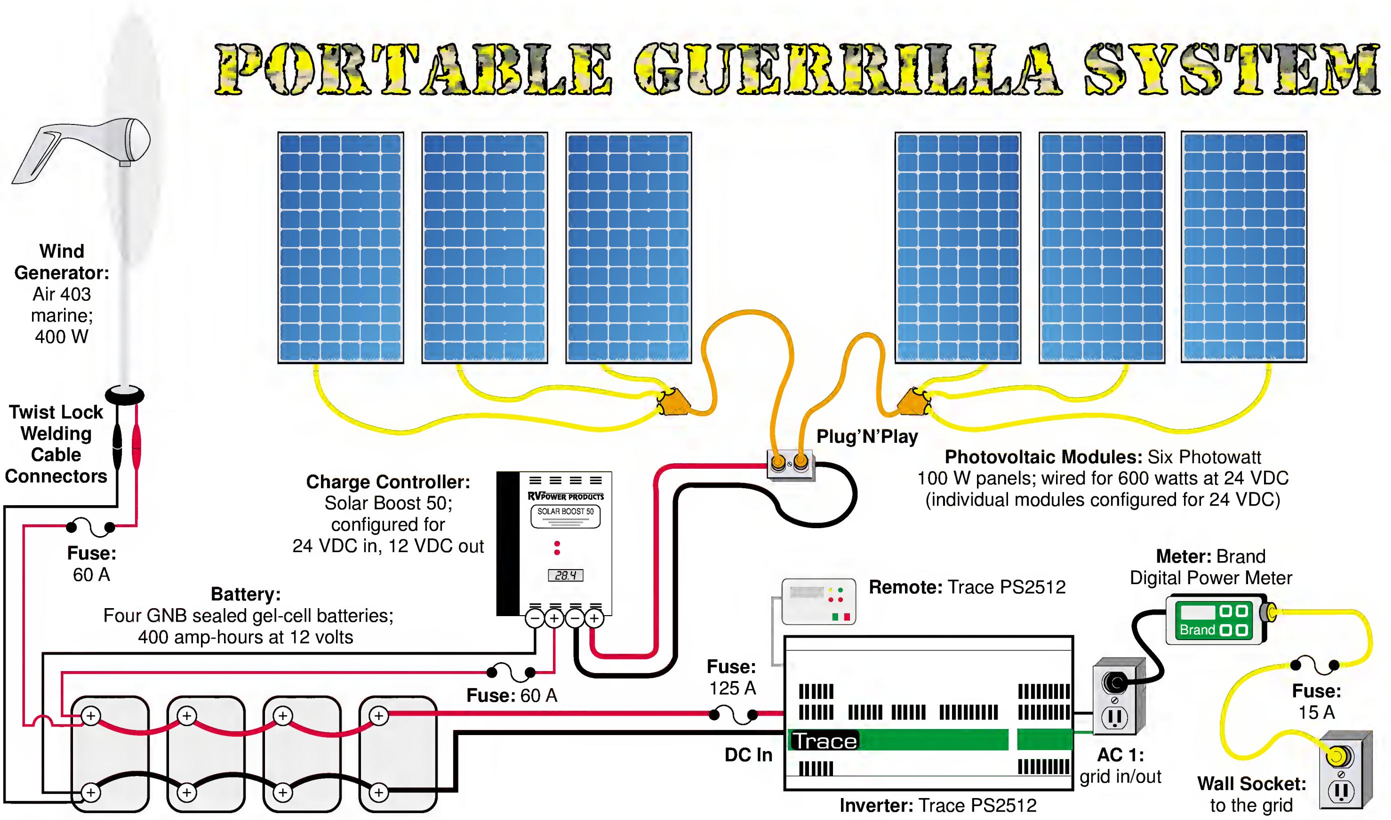
Inside the 2 inch (5 cm) pipe, I also have a rubber liner to help cut down on noise and vibration. This also closes up the 1/8 inch (3 mm) extra clearance between the pipe sizes. I drilled two holes at 90 degree angles from each other all the way through both pipes. With these, I can line up the holes when the pipe is all the way in, and bolt the inner pipe to the outer pipe with nuts and bolts that run all the way through. This helps ensure that *nothing* is going to shake the pipe out of the holding sleeve.

The wires for the generator run all the way down the length of the pipe, and come out the bottom of it, where I push and twist to lock them in. The actual power storage and conversion on the truck is a bit different from what I do at home. Since I work a few miles from home, an extension cord to plug into the grid is out of the question.

Generally when I am going to do the "collect energy while I'm working" thing, I throw four batteries into the truck, or maybe six if it's a really windy day. Before I throw them in, I'll have plugged them into the inverter, and sold them down to about 11 volts. Then while I'm working, the truck is in the parking lot, with the wind generator spinning away in the ocean breeze, charging my batteries back up. I don't have to worry about overcharge, since the Air 403 has its own built-in regulator.

Because I'm right on the ocean, there really are no wind interferences, so I don't need a tower to clear trees,

Solar powered lizard—the lizard's a load.



This system is not *NEC* compliant.

buildings, etc. The 8 feet (2.4 m) of pipe I have on the bumper is plenty long enough to get the wind generator up over the top of the truck and well out of reach of anyone who might want to get a closer look.

Just to be safe though, I have a sign that I hang on the back window saying, "Do not even think about stepping up for a closer look, unless you want body parts sliced off by the rotating blades." I also have a few more pages I printed up and hang in the window, briefly explaining exactly what is going on. When curious individuals come by and stop to look, they can get an education about renewable energy sources.

Portable Guerrilla

My setup may not be the most glamourous one out there, but it gets the job done, and can go anywhere I need it to. I have always been a gadget geek, and I love playing with new ideas and ways of doing things. But my main motivation for going guerrilla is that renewable energy is more reliable overall.

I looked into the rules and regulations of doing all this legally. But I didn't have a ton of cash to put out for a hookup the way "they" want it done, and I can't stand the ungodly bureaucracy you have to work through. So I said, "Screw this. Why go through that nightmare just because they don't want me cutting into their profits?"

So, hit the sell button I did, and with plenty of glee too. Now let's add the fact that more than once, our power has been turned off because of a hurricane threat, or a storm taking out something down the road a bit. I wanted some kind of backup system that was rather maintenance free, and well, unique.

Since part of the system had to be portable, I decided to build it so I could take the whole system where I needed it, when I needed it. It's actually kind of fun going to a campground, or a picnic or something, dropping a few solar panels out and watching TV or listening to my stereo out of the back of the truck. It gets a *lot* of attention when I tell folks that the sun is providing the electricity to do this.

My neighbors used to laugh about it when I was out in the yard shuffling panels around. But when the power went out for nine hours one day because a transformer blew up, I still had cold beer, TV, and lights. Then those laughs died down pretty quickly...

Guerrilla Solar Defined

Energy is freely and democratically provided by Nature. This century's monopolization of energy by utilities both public and private threatens the health of our environment. Solar guerrillas believe that clean renewable energy should be welcomed by utilities. But utilities and governments continue to put up unreasonable barriers to interconnection, pushing common citizens to solar civil disobedience.

Guerrilla systems do not endanger utility line workers (see *HP71*, page 58). They share clean, renewable energy with others on the utility grid, and reduce the need for polluting generation plants. When interconnection for small-scale renewables becomes fair, simple, and easily accessible to all, there will be no more need for guerrilla action.

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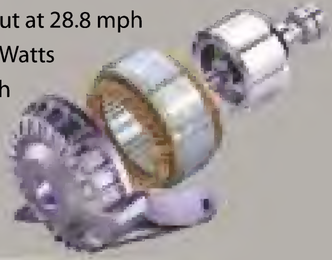

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Solar Hot Water for Cold Climates

Closed Loop Antifreeze System Components

Ken Olson

If you want a solar hot water system for your home and you live where it freezes, this article is for you. If you're installing your own system, it will help you get the right parts for a system that works. If you're planning to hire a professional, it will help you know what you're getting.

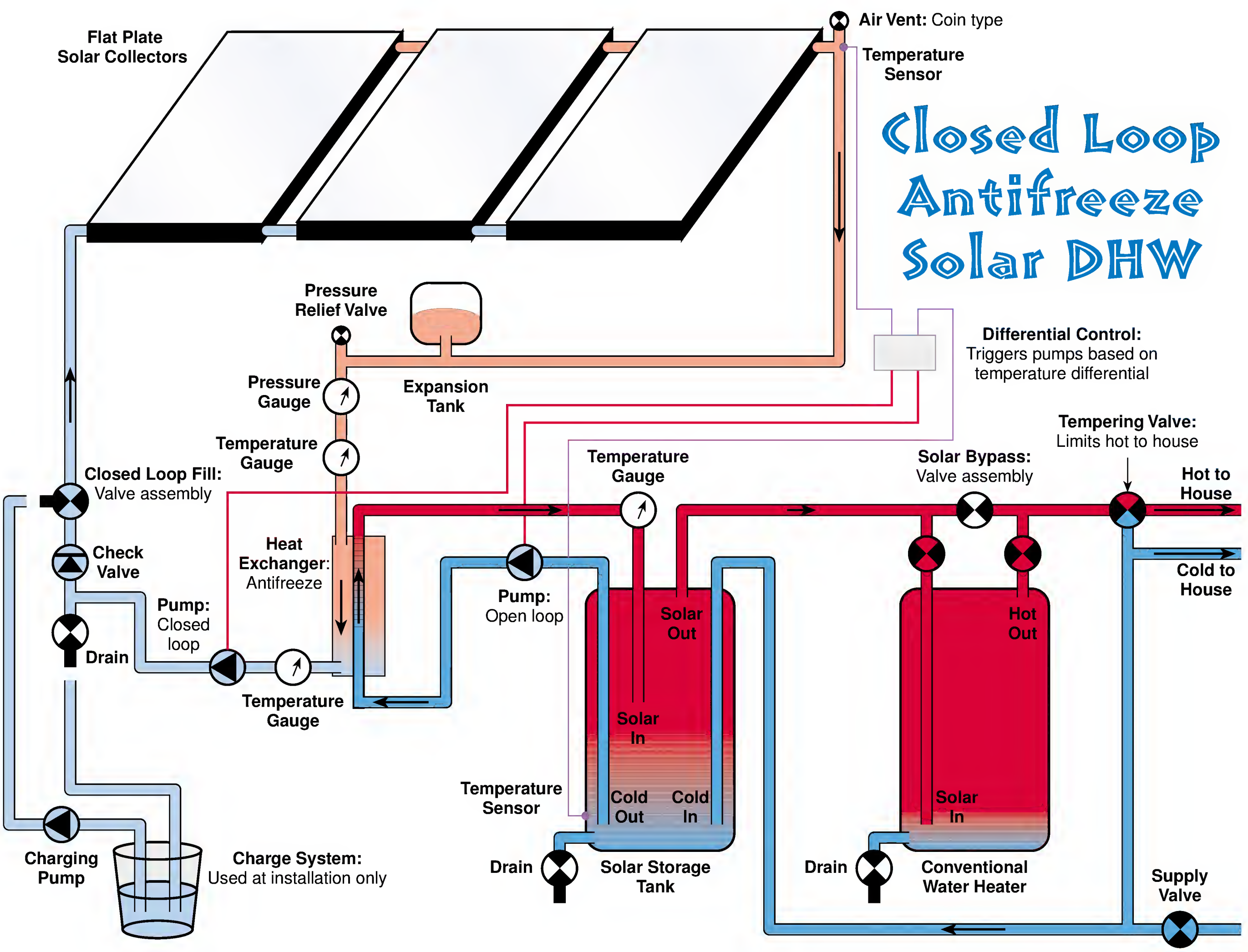
Solar Hot Water: A Primer (HP84) covered the fundamentals of solar hot water heating systems, including collectors, different types of systems, and rules of thumb for sizing. In this article, I focus on one system that is commonly used for solar hot water in freezing climates. You will learn the principles and parts that make up the "closed loop antifreeze" type solar water heating systems.

Closed Loop Antifreeze Systems

"Closed loop" is a general term for any portion of a hydronic heating system that is filled with a fluid at the time of installation. These systems remain closed to renewed supplies of corrosive oxygen. Open loop systems handle new water on a frequent basis, and must resist the deteriorating effects of exposure to a recurring supply of oxygen.

A "closed loop antifreeze" system is nearly identical in design to a conventional hydronic heating system; it simply uses solar collectors in place of a boiler. A hydronic heating system is any system that uses a fluid such as water, antifreeze, or oil as the medium of heat transfer. A "boiler" is where the fluid is heated. A closed loop solar hot water system includes

A closed loop module groups the major components on one board. This homebrew model by the author has functioned without fail since 1982.

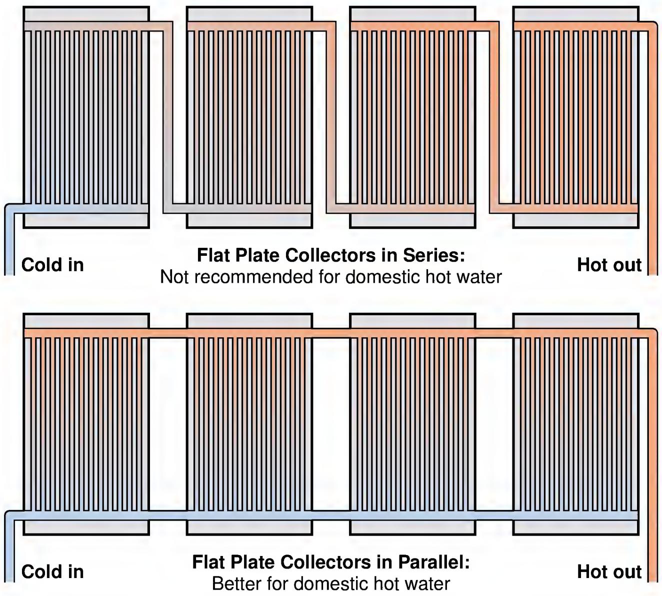


a closed loop and an open loop. The solar collectors are part of the closed loop. The open loop portion circulates the domestic water to be heated.

The major parts of a closed loop, antifreeze type system include solar collectors, circulating pumps, a differential control with sensors, heat exchangers, and storage tank. Lesser but essential parts include an expansion tank, pressure relief valve, check valve, drain/fill assembly, and pressure and temperature gauges.

Flat plate solar thermal panels are connected in parallel, and usually installed on a roof or mounted on a ground structure. The closed loop components can be pre-assembled into a "module" that can be fastened to the wall near the solar storage tank. Finally, the heat exchanger, solar storage tank, and collectors are connected to the closed loop module. Let's take a closer look at the function of each of these components.

Flat Plate Collector Interconnection



A flat plate (left) and an evacuated tube (right) solar collector.

Collectors

Flat plate collectors are most commonly used for low-temperature applications (up to 140°F; 60°C), such as residential domestic water heating and pool heating. Water passes through parallel copper tubes bonded to a flat copper sheet under glass, all enclosed in a weathertight insulated frame. For higher temperature applications (over 140°F), evacuated tube collectors are more efficient. The design of evacuated tube collectors reduces heat loss caused by convection, radiation, and conduction. (Flat plate and evacuated tube collectors were discussed in *HP84.*) To locate a supplier of solar collectors in your region, contact the American Solar Energy Society or the Solar Energy Industries Association or check your local yellow pages.

Circulating Pumps

Centrifugal-type circulating pumps are most commonly used in solar hot water systems and hydronic heating applications. Centrifugal circulating pumps are appropriate for their low power consumption, low

Fluid Basics

Fluid Flow

Rule of Thumb: For optimum flow rate through flat plate collectors, provide about 0.015 gallon (0.057 l) per minute (gpm) for each square foot (0.09 m^2) of collector. That translates roughly into about 1/3 gallon (1.3 l) per minute for each 3 by 8 foot (2.2 m^2) collector, and 1/2 gallon (1.9 l) per minute for each 4 by 8 foot (2.97 m^2) collector.

This will result in a 15 to 20°F (8–11°C) rise in temperature from inlet to outlet of the collector. Higher flow rates are unnecessary and use more electricity, but are not detrimental to performance. Lower flow rates result in less thermal efficiency because the collector runs hotter and loses more heat to the ambient environment. If you are using evacuated tube collectors, you could safely double the flow rate per square foot of collector.

Pressure & Head

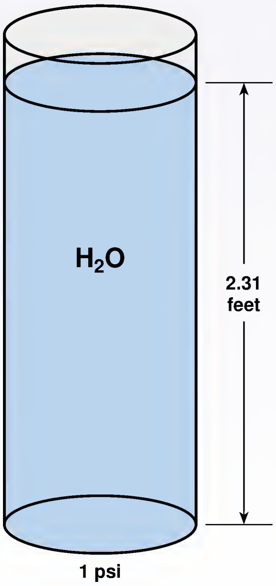
A column of water 2.31 feet (0.7 m) high exerts a pressure of one pound per square inch (psi). Therefore, 2.31 feet of head is equal to 1 psi. If you ever need to do the math to convert feet of head to psi, just divide feet of head by 2.31 or, conversely, you can multiply psi by 2.31 to arrive at feet of head.

head (in feet) ÷ 2.31 = psi

psi X 2.31 = head (in feet)

These equations are just two different ways of saying the very same thing—pressure. And the pressure is the force a pump must overcome.

The static head is equal to zero in a pressurized, closed loop system completely filled with fluid. Gravity is not a factor because the pressure is equal throughout the system. The amount of force (pressure) of the fluid above the discharge or outlet side of the pump is counterbalanced by the amount of force (pressure) of the fluid above the suction or inlet side of the pump; net static head is zero.



Circulating pumps in pressurized closed loop systems are low head circulating pumps, since they only need to overcome dynamic head, which is usually quite low. As a result, they have very low power requirements.

The Grundfos UP 15-42 F is a typical AC circulating pump for closed loop systems.

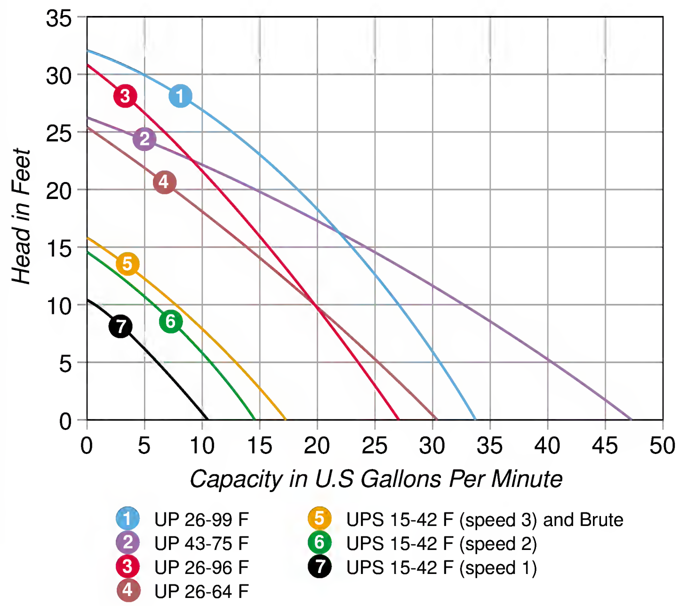
maintenance, and high reliability. They typically are made with cast iron, bronze, or stainless steel bodies.

For closed loop systems, (see *Rust Never Sleeps, HP84,* page 49), lower cost, cast iron circulating pumps are adequate. For the open loop part of the system, which circulates a replenishing supply of water, a bronze circulating pump is necessary. Stainless steel circulation pumps are used in pool systems and other applications where chemicals are present.

Once you know whether your circulating pump is to operate in a closed loop, open loop, or other particular environment, pump selection will be based on head and flow requirements. Head is the pressure the circulating pump must develop in order to create desired flow through the system. The overall pressure a pump must create is determined by the height the water must be lifted and the frictional resistance of the pipe.

Static head is pressure resulting from the vertical height and corresponding weight of the column of fluid in a system. The higher a pump must lift the fluid against gravity, the greater the static head it must develop. Dynamic head includes the frictional resistance of the fluid flowing through the pipe and fittings in the system. The pressure a pump must develop to overcome dynamic head varies with the size and length of the pipe, number of fittings and bends, and the flow rate and viscosity of the fluid.

Pump Curves for 5 Grundfos Brand Pumps



Circulating pumps are typically categorized for low, medium, or high head applications. Low head applications have 3 to 10 feet (0.9–3 m) of head; medium head applications, 10 to 20 feet (3–6 m) of head; and high head applications, over 20 feet of head.

A pump curve is supplied for each pump by its manufacturer (see the pump curve diagram above). The flow rate, in gallons per minute is shown across the horizontal axis. The vertical axis shows the pressure as measured in “feet of head.” Each pump has its own curve, which shows the volume of flow it will create at any particular head it must overcome. If you refer to the pump curves above you will see that the Grundfos model 26-96 F will push 20 gallons (72 l) per minute (gpm) against a resistance of 10 feet (3.1 m) of head. Ten feet of head is equal to 4.3 psi (10 ÷ 2.31 feet per psi = 4.3 psi).

For the solar closed loop, you can select a low head circulating pump with a cast iron or bronze body. You might consider the Grundfos model UPS 15-42 F to cover a wide margin of error. This model is a three-speed circulating pump that allows you to select the most appropriate speed once installed. A low head bronze pump will suffice for the water loop.

Whether open loop or closed loop; high, medium or low head; your local plumbing supply house probably carries an appropriate pump without special order. Most solar domestic hot water systems can be served by the Taco 008F, Grundfos 15-42 F, or Hartell MD-10IU pumps for the glycol closed loop; and by the Taco 006B, Grundfos 15-18 SU, or Hartell MD-3IU for the open loop domestic hot water.

Controller & Sensors

The controller is the brains of the system. It tells the pump when to turn on and off, based on collector and storage tank temperatures. All of its intelligence is based on determining whether the collector outlet is sufficiently warmer than the bottom of the tank to warrant turning the circulating pump on.

Sensors are located at the collector outlet, and at the bottom of the solar storage tank. These sensors are thermistors that change their resistance with temperature. The differential control compares the resistances of the two sensors. It turns the pump on when the collectors are sufficiently warmer (20°F; 11°C) than the bottom of the solar storage tank to collect useful heat.

The Independent Energy GL-30 is an example of a good differential control. It has an adjustable setting on the order of 5 to 25°F (3–14°C) temperature differential. These controls also have a high limit cut-out that will shut the system down once the tank reaches a predetermined high temperature, adjustable from 110 to 230°F (43–110°C). The GL-30 uses 10 K ohm sensors, which are the standard of the industry today. A 10 K sensor reads 10,000 ohms at 77°F (25°C). Temperature sensors must have the proper resistance to be compatible with a given controller. Sensors are available from the distributors who carry the controller you are using.

A differential pump controller senses temperature differences in various locations in the system.

Heat Exchanger

The heat exchanger transfers heat from the solar-heated closed loop to the domestic water. Factors that increase heat transfer are:

- Greater surface area
- High thermal conductivity
- Maximum temperature differential between the two fluids

Heat exchangers may be categorized as single wall or double wall, which refers to the number of barriers between the two fluids exchanging heat. Single wall heat exchangers are usually not permitted in potable (drinkable) water systems when a nonpotable heat transfer fluid is used. For example, systems that use glycol should not use a single walled heat exchanger because of the potential for contamination of the potable water.

Double wall heat exchangers are required to ensure that the heat transfer fluid will not contaminate the potable water. The space between the two walls of the heat exchanger is usually vented to permit detection of a leak.

A heat exchanger may be as simple as a copper coil within the storage tank, where single wall heat exchangers are permitted. Solar heated water is circulated through the coil with the help of a circulating pump. Heat is transferred by natural convection to the water within the tank.

External heat exchangers are generally less costly than a custom solar tank that includes an internal heat exchanger. External heat exchangers typically require two circulating pumps—one for the collector loop and another for the water loop. This uses more energy to run the second circulating pump, but it is more effective than an internal heat exchanger that relies solely on natural convection on the water side.

Heat transfer is driven by temperature differential. For this reason, heat exchangers are installed in a counter-flow configuration whereby the two fluids flow in opposite directions through the heat exchanger. This maximizes thermal heat exchange by maintaining the greatest temperature differential between fluids.

Air Elimination

Air is your enemy in a closed loop system. Air pockets can stop or slow fluid flow and defeat system performance. An air pocket on the suction side of the pump can cause the pump to burn out. All free air must be removed from the system when it is initially charged by the installer. A coin vent (you can open it with a coin or small screwdriver) is installed at the highest point in the system, which is usually at the outlet of the collectors. This allows you to manually vent air from the top of the system, and aids the installer or service technician in eliminating air from the system when charging it.

That is not the end of the saga on air. Over time, high temperatures and low pressures tend to drive dissolved gases out of solution, forming air bubbles. The air bubbles collect to form pockets in high spots within the plumbing, particularly at 90 degree elbows and fittings where fluid turns downward.

Coin vents can be installed at any place within the system where air is likely to collect. For large closed loop systems, air can also be eliminated automatically by use of an air eliminator and vent. The air eliminator has a washboard-shaped baffle to shake the air bubbles free from the fluid stream. A small reservoir space above the baffle allows air bubbles to collect where they can be vented out by either an automatic air vent or manually operated coin vent. Air eliminators are usually unnecessary on small closed loop systems.

Coin vents at high points in the system allow easy release of trapped air bubbles.

Selection of a heat exchanger is based on its capacity to transfer heat (in BTUs per hour) produced by the solar collectors. The manufacturer or distributor of the heat exchanger will specify which model is adequate, depending on the total square footage of collector to be installed. They will also specify a recommended minimum flow rate on the water side of the heat exchanger to achieve an adequate rate of heat transfer.

Check Valve

A check valve permits fluid to flow in one direction only. It prevents heat loss at night by convective flow from the warm storage tank to the cool collectors. Check valves may be of the “swing” type or the “spring” type.

Swing-type check valves should not be installed vertically upside-down, since they can hang open. If you are powering your circulating pump directly from a PV module, you should use the swing-type check valve. Low sun conditions produce lower flow rates, which may not be strong enough to overcome a spring-type check valve. For systems using AC circulating pumps, spring-type check valves are preferred. The spring provides a positive action against thermosiphon flow in either direction.

A check valve allows flow in only one direction, (see arrow).

Expansion Tank

An expansion tank allows for the fluid in the closed loop to expand and contract in the cycle of heating and cooling. Without the expansion tank, the plumbing would easily burst when the fluid is heated.

Diaphragm-type expansion tanks use an internal bladder and pressurized air chamber precharged at 12 to 15 psi. The solar-heated fluid expands in the closed loop against the bladder and pressurized air chamber. As the fluid contracts while cooling, the air chamber maintains pressure in the closed loop.

Diaphragm-type expansion tanks may be installed in any orientation, but if inverted such that the air chamber is above the fluid, it will continue to function even when the bladder eventually fails.

An expansion tank maintains pressure in the closed loop as system temperature changes.

The size of the expansion tank must be able to handle the expansion based on the volume, coefficient of expansion, and range of temperature fluctuation. These factors are considered in the rule-of-thumb recommendations below, which you may use to estimate expansion tank size based on total fluid volume.

The size and number of collectors, and the size and length of piping and fittings determine fluid volume. Use a #15 expansion tank for volumes up to 4.7 gallons (18 l), and a #30 expansion tank for volumes up to 12.5 gallons (47 l). Multiple expansion tanks can be used to increase capacity if necessary. Extrol diaphragm-type expansion tanks are readily found in most plumbing supply houses.

Pressure Relief Valve

Every hydronic heating system must allow for protection against excessively high pressures due to high temperatures. A pressure relief valve of 50 psi is typically adequate to protect closed loop plumbing from excessive pressures.

Temperature/pressure relief valves are not commonly used in the closed loop because high temperatures can be a frequent occurrence. Pressure-only relief valves are most commonly used. Once one of these valves opens, it is wise to replace it, since they often may not reseat, leaving a slow but persistent leak. Pressure relief valves should be fitted with a vent tube to direct vented fluid to a bucket or floor drain.

Gauges & Meters

A pressure gauge will tell you if the closed loop is within an acceptable range of pressure. A typical system pressure is on the order of 12 to 15 psi. So a gauge that registers up to 30 or 50 psi is suitable. The system pressure normally does not need to exceed 25 psi. A pressure gauge is used as a diagnostic tool to monitor the state of the glycol charge.

Two temperature gauges in the closed loop and one in the water loop are optional indicators of system function. One gauge on each side of the heat exchanger in the collector loop will show the temperature rise across the collectors and the temperature change across the heat exchanger.

A pressure gauge can show leaks in the loop.

Multiple temperature gauges help keep track of system funtion.

A temperature difference of 15 to 20°F (8–11°C) indicates effective operation. One temperature gauge in the water loop between the exit of the heat exchanger and the entry to the storage tank will display the current temperature of solar heated water.

Select a temperature gauge with a range of 0 to 250 or 300°F (-18 to 120 or 150°C). A hot summer day may produce water temperatures exceeding 200°F (93°C), although normal high temperatures are usually around 180°F (82°C).

Antifreeze

The collector loop circulates an antifreeze solution. Propylene glycol is the most common heat transfer fluid. It is a non-toxic substance, and more commonly used as a food additive, though it is not considered a potable fluid. Propylene glycol is usually mixed in a

50:50 solution with demineralized or distilled water. Inhibitors may be added to increase the life of the fluid, which breaks down over time due to overheating. It then forms a sludgy deposit that can clog the collector loop, as well as reduce the solution's effectiveness as an antifreeze.

Ethylene glycol should never be used. It is the common antifreeze used in automobile coolant systems. It is highly toxic, and will cause a great deal of discomfort and death if consumed.

At the time of installation, the collector loop is charged to operating pressure with a positive displacement pressure pump. Positive displacement pumps have the capability of creating sufficient pressure to lift the fluid the full height of the system, and bring the system to operating pressure, typically about 20 psi. Positive displacement pumps also create sufficient suction head to draw the charging fluid from the bucket.

The charging pump is not a fixture of the system. It is a separate piece of service equipment used by the plumber or mechanical contractor. It is connected to the drain/fill assembly in the collector loop, which consists of two boiler drains with a shutoff valve between them. Alternatively, you can save yourself a valve by replacing the shut-off valve of the drain/fill assembly with the system's check valve. This ensures that upon charging the system, fluid flows in one direction only, expelling air from the system.

Solar Storage Tank

Two tanks are more efficient than one. A solar storage tank may be installed in addition to your conventional hot water tank. Solar storage tanks are commercially manufactured with four ports at the top of the tank. This makes plumbing easy and convenient. You probably won't find the solar storage tank in stock locally unless you live near a metropolitan area, or there is a solar contractor with a steady volume of work in your area. So plan to special order that tank.

You can, however, easily modify a standard tank to perform just as well. It's easy, and it doesn't cost anything. But I'll leave the details for another time.

For those summer months when you can be satisfied with solar hot water alone, you can install a "bypass valve assembly" between the solar storage tank and the backup water heater. The solar bypass consists of three valves (or two 3-way valves), which allow you to give your conventional water heater a summer vacation and supply the house with solar heated water directly.

If you like that idea, you should add a measure of protection for those days when you just might get water hotter than you can handle. A tempering valve can keep

Three valves make up the drain/fill assembly.

you from getting scalded when your solar heated water is hotter than you normally enjoy from a thermostatically controlled conventional tank. The tempering valve is installed between you and your hot water system. With it, you can set the desired maximum temperature of the water delivered to the tap. Hot water enters one side, cold water, if necessary, enters from the bottom and mixed water goes out to the tap.

Every component mentioned so far in this article, with the exception of the solar collectors, solar storage tank, and heat exchangers, is commonly available at your local plumbing or heating supply house. You can special order these items, but you'll probably find more knowledgeable service at a solar supply house. Of course, most solar supply houses will carry the common parts as well, and can give you better advice when it comes to solar heating systems.

Putting the Parts Together

As you can see, closed loop antifreeze systems have quite a few components. In this article, I've discussed the function of each component within the system, along with principal selection criteria for each.

For the solar closed loop, you'll need a low head cast iron or bronze circulating pump, double wall heat exchanger, expansion tank, check valve, one or two coin vents, pressure relief valve, pressure gauge, and two temperature gauges.

For the open water loop, you'll need a low head bronze circulating pump and a temperature gauge. A differential control with two sensors will turn the system on and off, and a solar storage tank will hold your daily catch.

Of course, you'll need a bunch of fittings and valves, and don't forget an insulating blanket for that tank and pipe insulation to make it efficient. With good plumbing skills and an understanding of how the parts go together, you can find yourself in hot water too, from the sun that is.

Access

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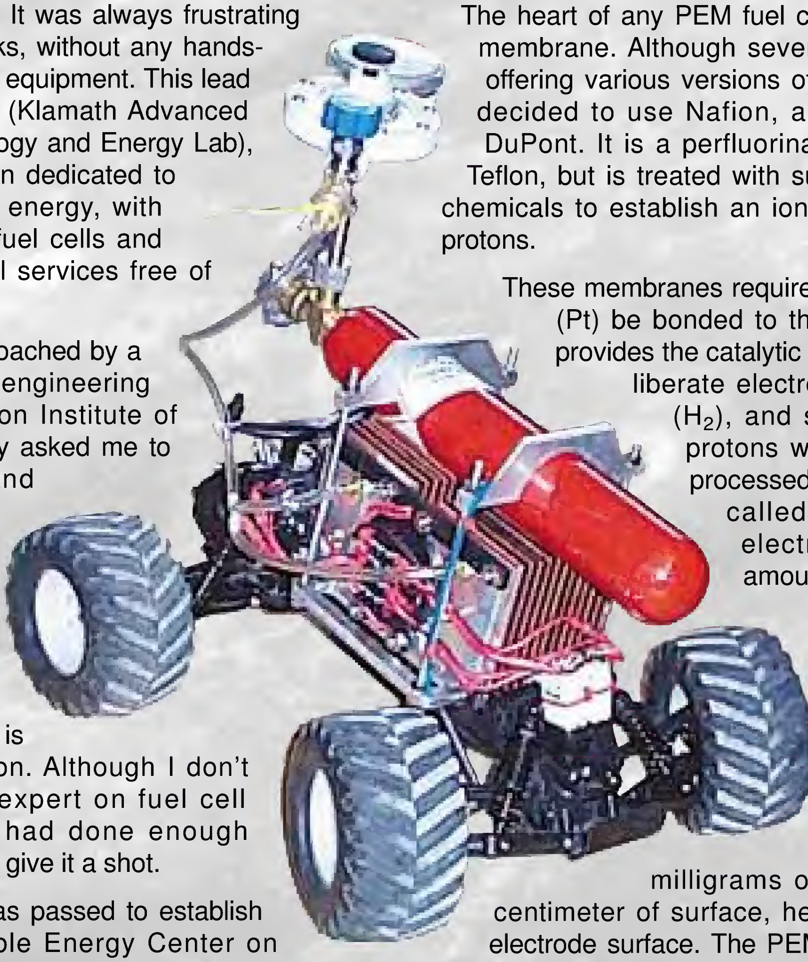
Homebrew Fuel Cell & Hydrogen Electrolyzer

Larry Elliott

For the past several years, fuel cells and hydrogen have been very hot topics in the news. Unfortunately, unless you are a well-funded university or a large corporation, purchasing a fuel cell or hydrogen electrolyzer has been next to impossible.

I've studied and researched fuel cells and hydrogen for several years, and I find them fascinating and technically challenging. It was always frustrating to learn only from books, without any hands-on experience with real equipment. This lead me to create KATTEL (Klamath Advanced Transportation Technology and Energy Lab), a nonprofit organization dedicated to advancing renewable energy, with special emphasis on fuel cells and hydrogen. We offer all services free of charge.

Last winter, I was approached by a group of mechanical engineering students at the Oregon Institute of Technology (OIT). They asked me to help them design and build both a proton exchange membrane (PEM) fuel cell and an electrolyzer to produce hydrogen from water. It would be a senior project, which is required for graduation. Although I don't consider myself an expert on fuel cell design, I felt that I had done enough homework and study to give it a shot.



Recently, legislation was passed to establish the Oregon Renewable Energy Center on campus. This fall, OIT will offer bachelor's degrees in engineering with emphasis on PV, fuel cells, and other renewable technologies.

Design Goals

We decided early on that the size of the fuel cell and electrolyzer should be kept relatively small to keep costs down. Fortunately, I had previously designed a 90 watt PEM fuel cell, as well as a 400 watt PEM electrolyzer. Both were only on paper, and had yet to be proven. The designs seemed to be a good match for supplying adequate power and fuel to the remote-controlled model car the students wanted to power. The car is a small, 7.4 volt unit that weighs about 6 or 7 pounds (3 kg).

Materials

The heart of any PEM fuel cell or electrolyzer is the membrane. Although several companies are now offering various versions of these membranes, we decided to use Nafion, a proven material from DuPont. It is a perfluorinated polymer similar to Teflon, but is treated with sulfur, carbon, and other chemicals to establish an ion path that can conduct protons.

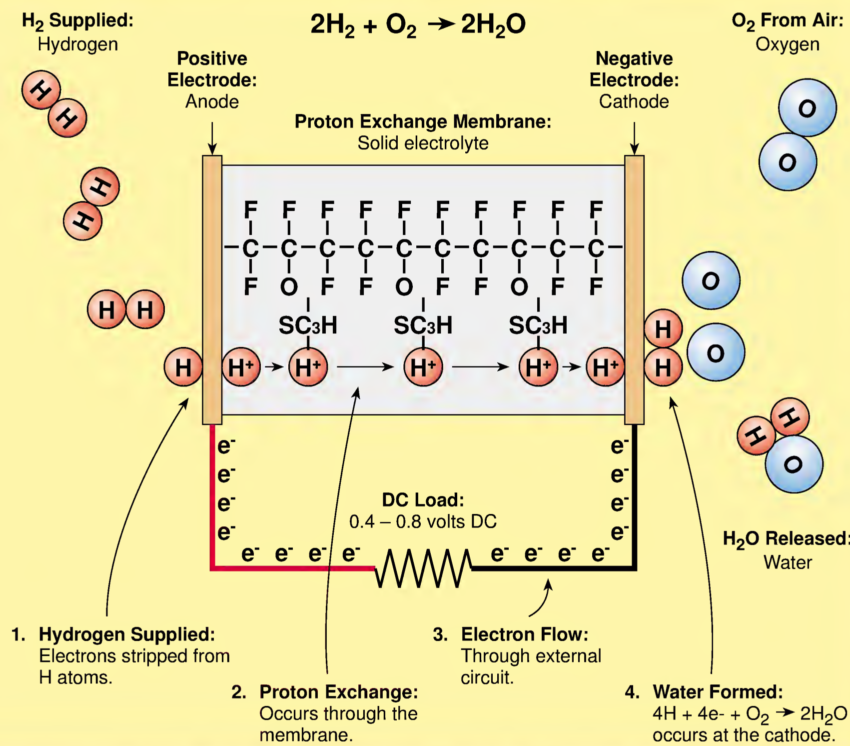
These membranes require that a layer of platinum (Pt) be bonded to the active surfaces. This provides the catalytic action necessary to help liberate electrons from the hydrogen (H_2), and supports a reaction of protons with oxygen (O_2). When processed, these membranes are called MEAs—membrane electrode assemblies. The amount of platinum is usually measured in tenths of a milligram per square centimeter.

Our membranes were ordered from Ion Power in Delaware, and have approximately 0.4 milligrams of platinum per square centimeter of surface, heat-bonded to the PEM electrode surface. The PEM active area is one mil thick, and is mounted in a Kapton frame. Moisture management of the PEM is important, so we went with a very thin membrane to help in this area.

PEM Fuel Cell Basics

Hydrogen is composed of one proton and one electron. As hydrogen enters the anode diffuser, it contacts the platinum catalyst layer on the membrane, and an electron is stripped off. The electron travels to the external load. The proton passes through the membrane and recombines, via another platinum catalyst at the cathode, with oxygen and the electron coming from the load. The byproduct is water, which is usually shuttled back to the anode* to keep the membrane hydrated. It also keeps the cathode from "drowning."

*Anode and cathode are defined by the direction of proton flow (from anode to cathode) rather than electron flow.



Because the PEM fuel cell and PEM electrolyzer are very similar in their operation, we decided to build both from the same basic materials. Most PEM fuel cells use machined graphite plates that serve as both gas diffuser and conducting electrode. Machining this graphite requires precision. It can also be quite dusty and dirty, and without use of a CNC (computer numerical control) milling machine, it can be very labor intensive.

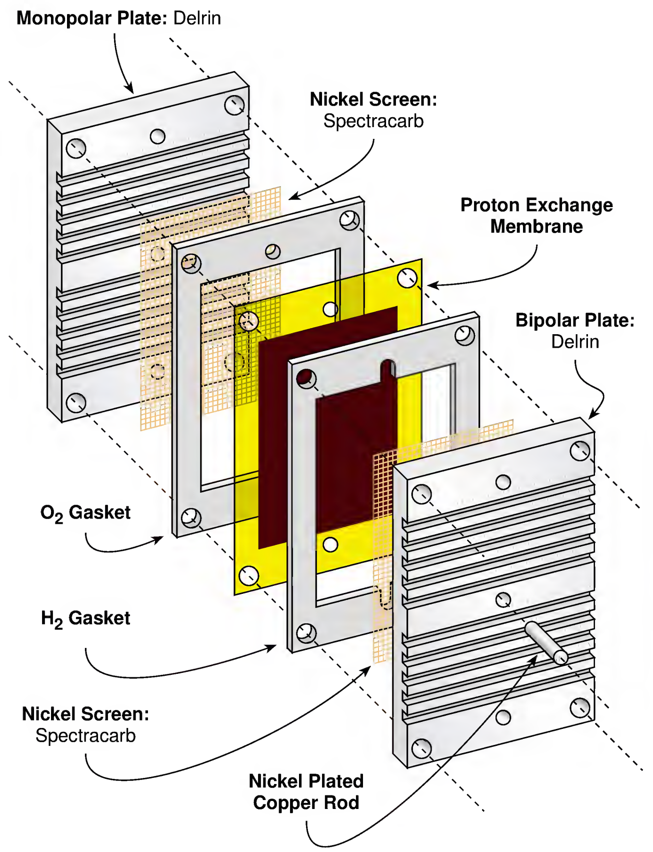
As a compromise, we decided to use a very stable and cost-effective plastic known as Delrin, generically known as acetal plastic. This would be easy to machine, serve as a good insulator, resist moisture in the electrolyzer, and be nonreactive to hydrogen and oxygen. A combination of nickel wire mesh and Spectracarb carbon paper was selected to serve as our combination electrode/gas diffuser. Along with some silicon rubber for gaskets and stainless steel hardware, our materials were easy to obtain, and the costs were kept low.

Designing for Power Input & Output

An individual solar-electric cell has a fixed voltage of approximately 0.5 volts. The current output is primarily a function of the surface area exposed and the intensity of the sun. A fuel cell is very similar in its operation. A typical cell voltage is in the range of 0.4 to 0.8 volts, and the current output is a function of surface area exposed to hydrogen and oxygen flow. Real world performance is determined by temperature, gas diffusion rate, internal resistance, and other variables far too extensive to cover in this short article. We had to use many of the same techniques in sizing our fuel cell stack and electrolyzer that are used in sizing solar arrays.

A proton exchange membrane being assembled into the stack of a fuel cell.

Stacking of One Proton Exchange Fuel Cell



Using published performance data for prototype and commercial fuel cells, we based our power output on a current density of 400 milliamps per square centimeter of active membrane surface and 0.6 volts per cell. We decided to build two separate cell stacks of twelve cells each, with each cell having an active area of 3.5 square inches (22.5 cm^2).

We would have twelve cells in series, giving an expected 7.2 volts, and two stacks in parallel to provide an expected 9 amps each. This would give a power output of 130 watts (7.2 volts x 9 amps x 2 = 130 watts).

For our electrolyzer design, we knew from published figures that 1.23 volts was the theoretical voltage needed to separate the hydrogen/oxygen bond. We wanted to be able to run the electrolyzer from a 12 volt nominal solar-electric panel. After taking voltage readings from my three, 1980s vintage General Electric PEM electrolyzers, we selected 2 volts per cell as the design voltage. This would mean that our eight-cell stack would operate at close to the maximum power point of most 12 volt silicon solar cell modules. We expected to limit the current to no more than 20 amps.

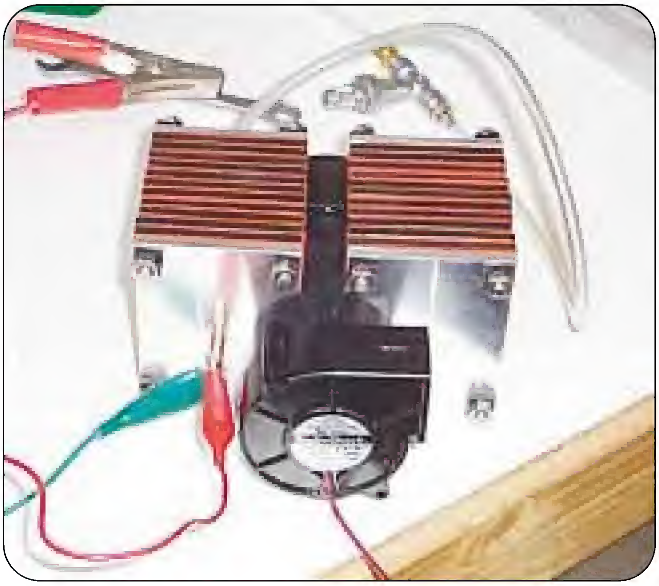
Design Details

A fuel cell is very similar to a battery except for the fact that it is continuously charged by the flow of hydrogen and oxygen. It has a cathode or negative pole where oxygen reacts, and an anode or positive pole where the hydrogen reacts. The trick in a fuel cell is to get the hydrogen to flow on one side of the membrane and the oxygen on the other. In a single cell, this is not too difficult. When cells are stacked, the mechanics of getting proper gas flow and air flow to each cell is harder.

In our design (see the diagram at left), small grooves (1/16 inch; 3 mm) are cut into the cathode face of each Delrin bipolar plate. This allows air flow across the entire cathode surface. The nickel mesh and carbon paper (Spectracarb) are set between the membrane surface and the Delrin. These are the electrodes that contact the platinum surface of the membrane. The Spectracarb is a good conductor and gas diffuser, and helps manage the moisture generated on the cathode side of the membrane.

The anode and cathode electrodes are connected in series by a small, nickel-plated, copper rod that runs through the Delrin plate. Hydrogen gas flow is directed to the anodes by way of a series of holes and gas channels machined into the bipolar plates and gaskets. A small (1/16 inch; 3 mm) hole is machined at the opposite end of each anode. It allows the hydrogen to flow up and across the nickel mesh screen and Spectracarb, allowing good diffusion of the hydrogen across the entire membrane.

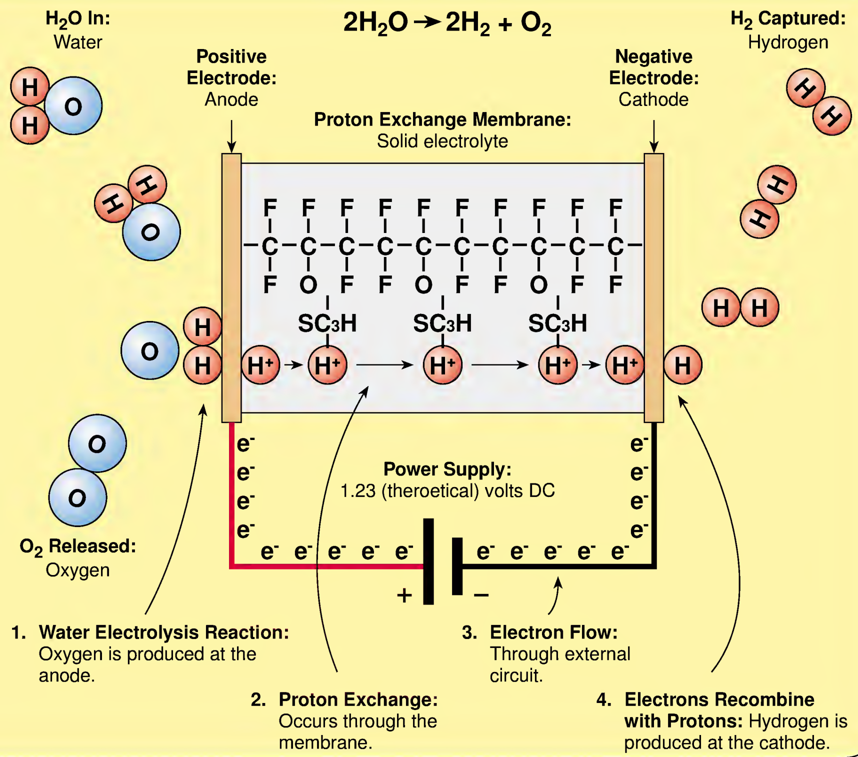
Two fuel cell stacks in parallel, 7.2 volts each at 18 amps for a total of 130 watts. The fan forces air through the stacks, providing oxygen for the reaction.



PEM Electrolyzer Basics

In the electrolyzer process, water is distributed to the anode side of the membrane. With sufficient voltage, the bonds between the hydrogen and oxygen in the H_2O are broken by electromotive force (EMF) and the catalytic action of the platinum. The membrane segregates the H_2 from the O_2. The proton migrates through the membrane and recombines with the returning electron. We then have one proton and one electron on the cathode* side becoming H_2.

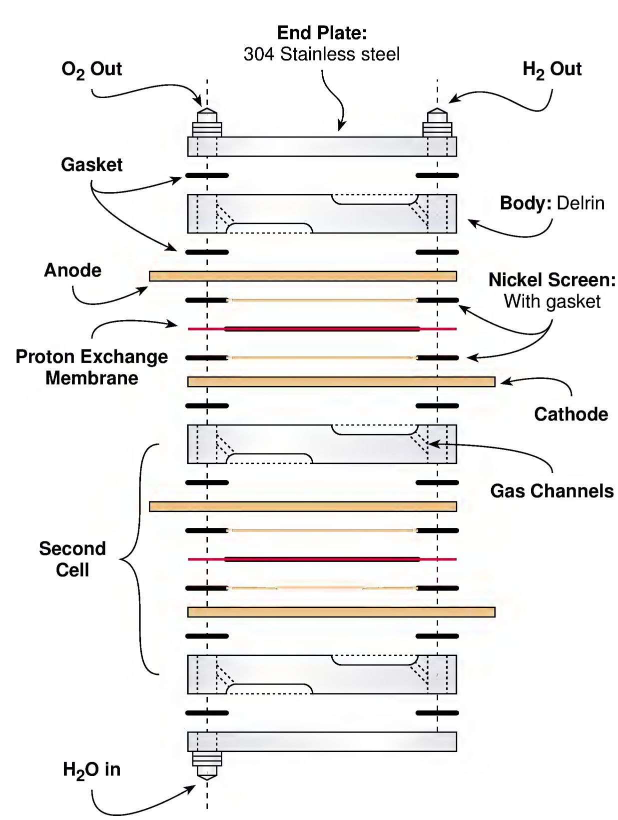
*Anode and cathode are defined by the direction of proton flow (from anode to cathode) rather than electron flow.



Because the contact pressure in the junction between the membrane and the electrode is critical in keeping resistance and voltage drop to a minimum, a machined and very flat aluminum plate is set at both ends of the stack. Using stainless steel rods passing through the stack at each corner, controlled pressure can be applied. A spring washer, known as a Bellville washer, is used under each bolt head to help control compression as the stack heats up and expands.

The PEM electrolyzer stack—eight cells operating at 2 VDC nominal per cell—separates the hydrogen and oxygen atoms of water molecules.

Electrolyzer Stack Showing Two Complete Cells



Membrane and nickel electrode screens for the PEM electrolyzer.

The homebrew fuel cell on the test bench.

Assembly & Test

Careful assembly of a cell stack is critical to good operation. With concerns for gas flows, conductivity, and proper contact pressures, assembly becomes very labor intensive. Even with the best commercial designs, the labor cost component is high. Proper design and automation can address most of this at the commercial level.

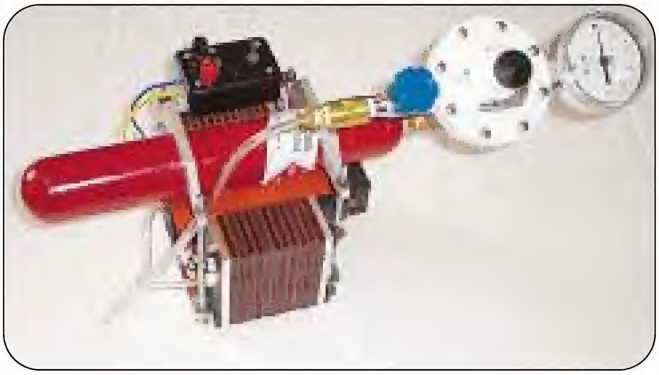
We did many calculations of performance based on variables such as gas flow, temperature, and pressures. It was the real world testing that proved to be the most rewarding as a learning experience. We used a fairly sophisticated test setup. It included a digital mass flow meter calibrated for H_2, a velocity meter and manometer for air flows, a pressure gauge that accurately reads to 1/10 psi, and several very precise pressure regulators and needle valves. Most of this equipment was purchased as surplus from a local supplier. We acquired a fairly sophisticated lab on a bargain basement budget.

Although a fuel cell is similar to a battery in that they both produce DC power, the similarity ends there. In the fuel cell, gas flow and pressures, temperature, and loads all have to be adjusted and accurately balanced. When we did an open circuit test of a single cell, we were very pleased with the performance. We were not ready for some of the later surprises when testing the assembled stacks.

A fuel cell uses hydrogen as a fuel and the oxygen in the air as an oxidizer. This is much the same as an internal combustion engine, except for the fact that the fuel is not burned. The process is more like rusting than like fire or combustion. Just as an engine can be starved for air when choked out with a mixture too rich with gasoline, a fuel cell must also have a balanced fuel-to-air (or stoichiometric) ratio, so all hydrogen gets turned into power and H_2O.

The air in our fuel cell is forced into the cell stack and across the membranes using a small, 1 watt, brushless DC fan. To simplify the design, we decided to suck the air in, instead of blowing it in under pressure. We assumed it would make little difference. After failing to get the cell stack to deliver anywhere near full output, we realized that we needed to change the air flow direction. Careful observation of current and voltage levels relative to air and fuel flow lead us to this conclusion. Because air is composed of only 20 percent oxygen, any increase in pressure also increases oxygen density for a given volume flow rate. After a change of fans and manifold, our power output doubled.

The next problem was internal resistance causing excessive voltage drops and excessive heat under load. The problem proved to be a lack of contact pressure between the membrane and the electrodes. After carefully tightening the compression bolts, we increased our voltage by 2 volts at the same load



The completed hydrogen PEM fuel cell.

current. We originally designed the stack to operate with H_2 under a fixed pressure. After careful testing, we found that a small weep hole was needed to let a little of the hydrogen flow over the diffuser layer and exit at the top of the cell stack.

A Necessary Addition

Our remote control car has high and variable surge loads. Our fuel cell stack lacks a fuel-control management circuit, and has rather poor surge capacity. So a capacitor was placed in parallel with the load to aid in starting the motor. We managed to obtain capacitors with extremely high storage per unit weight. Maxwell Technologies manufactures a complete line of these ultra-large capacity, PowerCache capacitors rated at up to 2,500 farads.

Large size capacitors such as these are being added to hybrid and fuel cell autos for some of the same reasons. These capacitors are excellent choices for delivering large bursts of power, while batteries are better at delivering a lot of energy over time. We purchased ten PC10s. These capacitors, at ten farads, weigh just over 6 grams (0.2 oz.), and are smaller than a postage stamp. Yet they deliver more than 2.5 amps at 2.5 volts. They have proven to be indispensable in leveling out the surge loads placed on the fuel cell, and have increased overall system efficiency.

From H_2O to H_2 & Back Again

The device that made this project especially interesting was the PEM electrolyzer. It converts water into hydrogen and stores it at pressure. Later, we run the fuel cell from the same hydrogen, converting it back to water. This is nothing short of magic, with a technological twist. The sidebar on page 55 shows a schematic of the reactions taking place in the electrolyzer.

Unlike many designs, the PEM uses no acids or bases as electrolyte. The PEM membrane acts as the electrolyte and also serves to keep the oxygen and hydrogen separated. The beauty of this design is that the hydrogen creates its own pressure. It has no known upper limit except for the mechanical strength built into the cell design. It also produces 99.9 percent pure gas.

Using Delrin and nickel mesh and plate, an eight-cell stack was fabricated. The diagram on page 55 shows its assembly. The testing is where some interesting problems cropped up.

With raw Nafion in a single, clear Plexiglas cell, we could generate gases at a pretty good rate. Unfortunately, when we assembled our stack using this raw Nafion, it refused to electrolyze for long. It would gas for several minutes as the voltage dropped lower and lower. Finally it would just stop conducting. Disconnecting it for several hours seemed to restore conduction, but then it stopped again.

We needed a platinum layer on the anode side to help keep the process going. It was also discovered that the voltage across the PEM must be carefully regulated to maintain conduction. This conclusion was derived with a lot of blind testing. So far, we don't understand the relationships between voltage and generated pressures and what reactions are taking place within the membrane. We hope we can discover it on our own, so

Oregon Institute of Technology students Dan Hill and Jacob Pelzer.

OIT Fuel Cell and Hydrogen Electrolyzer Costs

Raw materials	*Cost (US$)*
24 membranes	$1,920
Raw Nafion 117, 0.41 x 0.41 m^2	310
Liquion compound, 0.125 litre	275
10 PC10 capacitors	100
1 gram 20% Pt on carbon	100
Carbon paper, 648 $inch^2$	95
Delrin sheets and rods	90
Silicon rubber gaskets, 9 sq ft x 1/8 inch	75
Misc. stainless steel fittings and valves	60
Fan and manifold	19
24 Bellville washers	16
Nickel grid (free samples)	0
Total	$3,060

we can build a more precisely regulated DC control circuit. Using a 20 percent platinum black-on-carbon compound and liquid Nafion (known as Liquion), we were able to heat-press a layer and reassemble the stack. Our design is, at best, 50 percent efficient now, but with further redesign, 85 percent may not be an unrealistic goal.

In our system, we stored the hydrogen at fairly low pressures of less than 100 psi, in a 2 cubic foot (0.06 m^3) aluminum gas cylinder. Since we are going from a dense liquid to a very light gas it stands to reason that the electrolyzer becomes self-pressurizing when the gases are contained within a closed vessel. One interesting discovery was the fact that the electrolyzer acted as a fuel cell once the power was disconnected. I think a practical, combination fuel cell/electrolyzer is quite possible, but it would require a fair amount of redesign. Additional detailed information on this process is available at Proton Energie's web site at: www.protonenergy.com or Stuart Energy at: www.stuartenergy.com.

Renewable Hydrogen

We pursued this method of hydrogen production in spite of criticism from those who felt it was wasteful to use renewable energy to power the less than 100 percent efficient electrolysis process. Few seem to consider the fact that extraction of fossil fuels, in many cases, uses enormous quantities of fuel just to get it to the end user. There are, in fact, many good arguments for the use of this PV, electrolyzer, hydrogen storage, fuel-cell process.

Electrolyzers that use renewable energy to convert water into hydrogen gas could expand the use of solar and wind power. Both of these sources of energy are highly variable. Sun is available less than half the day, and wind is highly erratic, even in good wind regions.

This means that we now use the grid, lead-acid batteries, or some other means to store this energy. In the case of the grid, it is not truly stored, and the true overall efficiency is rather poor. Lead-acid batteries can never serve as a practical storage medium if off-grid systems become ubiquitous.

I have yet to see a solar or wind system that lacks a voltage regulator. Most of these regulators dump excess energy when the battery is full. Would it not be more efficient to *use* the wasted energy to electrolyze water?

Water is available universally, worldwide. When 2.3 gallons (9 l) of water is turned to hydrogen, the energy equivalent of one gallon (3.785 l) of gasoline is liberated. Even the most advanced battery system could store only a fraction of this energy when weight and volume are taken into account. When consumed, hydrogen turns back to water, whether burned or run through a fuel cell.

With more research, electrolyzers can reach as high as 85 to 90 percent efficiency. Fuel cells have the potential to reach 75 or 80 percent efficiency. With combined cycle efficiencies of over 60 percent, we exceed the overall efficiency of most fossil fuel extraction and any form of grid power. All of this gives us good reasons to pursue and further promote the electrolysis process.

Our adventure into fuel cell and electrolyzer design and fabrication has been very rewarding. We were able to learn a lot about the electrochemistry involved, in a hands-on manner. It greatly increased our interest in promoting this technology as a practical and ultimately cost-effective addition to the ever-expanding renewable energy inventory. We hope to provide more detailed updates in future issues of *Home Power.*

Access

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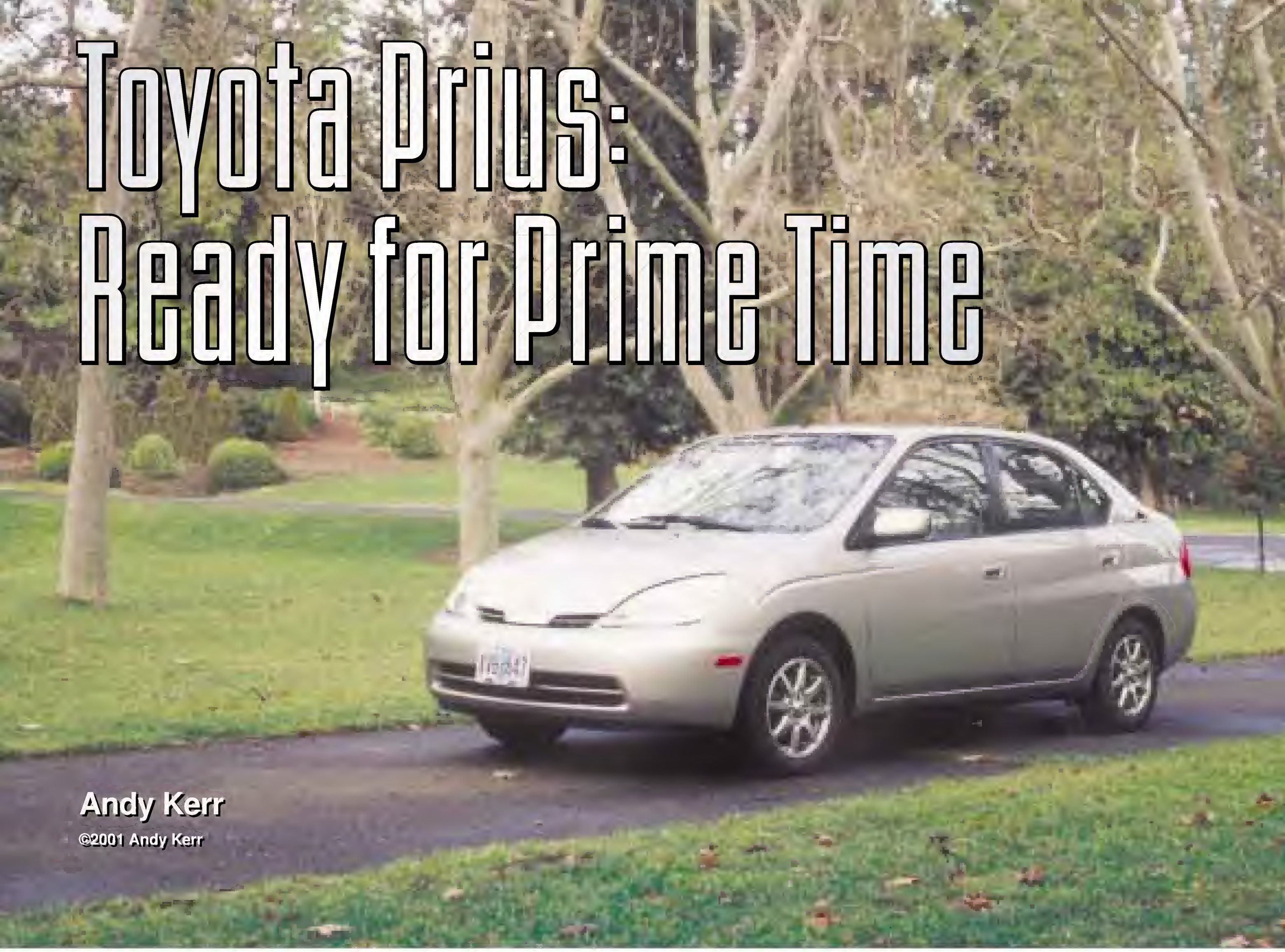
Toyota Prius: Ready for Prime Time



Andy Kerr

In late 1998, Toyota first announced its intent to produce a hybrid gasoline-electric vehicle for U.S. sale. The first Toyota Prius (2001 model year) left dealer showrooms in late summer of 2000. More than 50,000 are already on the road in Japan, where they are manufactured. In the United States, demand exceeds supply—there is currently a five-month waiting period. Toyota claims it will produce 300,000 hybrids by 2005.

The Prius ("to go before" in Latin) propulsion system is a gasoline-electric hybrid that uses a small gasoline engine, a motor/generator, and a "traction" battery. It also has a normal car battery for accessories. The electricity is generated onboard by the gasoline engine turning the motor/generator, which helps to power the wheels or charge the traction battery as needed. At low speeds, the traction battery can provide all the power to the wheels; during acceleration, it assists the gasoline engine.

The car is still fundamentally powered by an internal combustion engine. Its lower pollution levels are attributable to a very clean burning engine and the overall design that maximizes mileage. From insulation (which reduces the air conditioning load) to the aerodynamic design, the vehicle is engineered to perform adequately with the smallest possible engine.

Using a special Toyota Web site, my wife and I ordered our Prius on the first day possible, June 25, 2000. Our beloved 1990 Subaru had already long been on life support, but nonetheless, we kept the faith and waited anxiously for delivery. We wanted the least polluting, most fuel efficient vehicle available. And we also wanted a Toyota since we were very satisfied with our 1995 Toyota four-cylinder 4WD pickup. Our Prius arrived on September 15, 2000.

Though it looks like any other car, the Toyota Prius uses advanced designs for maximum efficiency.

Cleaning Up Our Act

The U.S. Environmental Protection Agency (EPA) rates the Prius at 52 miles per gallon (22 km/l) city, 45 mpg (19 km/l) highway, and 48 mpg (20 km/l) combined. Unlike every other car on the road, the Prius gets better mileage in town than on the open road, due to a combination of factors. The engine shuts off when the car is stopped, and the motor/generator uses excess energy from the engine, which has been stored in the battery. Despite what we may all wish, most of us do the majority of our driving in short, low-speed trips, which happens to be what the Prius does best. But even on the freeway, with a cruising speed of 75 mph (120 kph), we are getting 41 to 44 mpg (17–18 km/l).

The only current competition in the hybrid arena is the Honda Insight, a smaller (two passenger, two door) and more polluting vehicle. The Insight is classified as an ultra low-emission vehicle (ULEV), while the Prius is a Super ULEV (SULEV), emitting about 90 percent less pollution (other than carbon dioxide) than a standard modern vehicle on the road today. The Prius runs 75 percent cleaner than a ULEV.

Until concerns about global warming surfaced, carbon dioxide wasn't considered a pollutant. It doesn't smog our view like the ozone precursor nitrogen dioxide, or affect our breathing like particulates (soot). The amount of CO_2 a vehicle produces is directly correlated with fuel economy. The more fossil fuel burned, the more CO_2 emitted.

Today's average car on the road is a low-emission vehicle (LEV). Also available are zero-emission vehicles (ZEVs), such as the Toyota RAV-4 electric vehicle. Of course, it's only possible to call them ZEVs if you ignore the upstream pollution caused by generating the electricity. While it is less polluting to make electricity from fossil fuel (such as coal or oil) and transport it across the grid to power an electric vehicle's batteries, it still causes pollution. The pollution just goes up a large smokestack rather than out a little tailpipe.

Another option is a hydrogen-powered vehicle. Most hydrogen today comes as a byproduct of liquid fossil fuel production. So hydrogen-powered cars are not pollution free either, unless the fuel is made using renewably generated electricity.

The other major automakers are promising their own hybrid offerings, but all are still vaporware. Perhaps they'll be supplanted before they are released by fuel cell powered vehicles, but these are even more vaporous at this time.

Distribution Channels

Our local Toyota dealership knew next to nothing about the pending Prius. I ended up being pushier as the car buyer than the car salespeople were. Fortunately, our Toyota dealer did decide to spend the several hundred thousand dollars for new equipment and training necessary to service the Prius. Not all dealers have.

With a coefficient of drag of 0.29, the Prius is as slippery through the wind as some sports cars.

Under the hood—the gasoline engine and electric motor/generator.

Though it took longer than expected, the process went rather smoothly, in spite of some irregularities. With the novelty and limited production, the normal sales and distribution channels weren't yet working when we bought our Prius. We were getting e-mails from Toyota regional representatives about when the vehicle would arrive, and then informing our salesperson, who informed her superiors. We knew more about the Prius than anyone at the local dealership. We trust this won't be the case when the first service is necessary.

Marketing

In its marketing literature for salespeople, Toyota describes the probable Prius buyer profile as one of three major mindsets:

- Technology pioneers—those who are interested in the latest technology, and who must be the first on the block to own this technology.
- Environmentally friendly—those "somewhat concerned" about the environment who are looking for easy expressions of their concern without being inconvenienced.
- Value conscious—those desiring a vehicle that provides the ideal combination of high fuel economy, low maintenance costs, and an affordable price.

They had us pegged. I'm all three, and my wife is the latter two. We wanted the convenience of a "regular" car. We didn't want the limited range or carrying capacity of the current crop of all-electric automobiles. We wanted more than a golf cart on steroids. We didn't want any vehicle that required the constant care and feeding of a bank of batteries, or one that couldn't get too far from a charging station. We didn't want to be hustling used french fry oil from restaurants. We wanted a car that seats four in almost any combination of people and dogs. We wanted a normal car, with all the safety features and a modicum of conveniences.

The Prius is a modern, good looking car that includes halogen headlamps, intermittent wipers, automatic transmission, power steering, remote powered outside mirrors, cupholders, quartz clock, AM/FM/CD/cassette player with four speakers, power windows and locks, ABS brakes, front airbags, keyless entry and antitheft systems, and other comparable features.

It meets current federal motor vehicle safety standards. It seats five (four comfortably) and weighs 2,765 pounds (1,254 kg). Suspension features include independent MacPherson struts with stabilizer bar for the front end, and a torsion beam with stabilizer bar in the rear.

The Prius comes with a basic 36 month/36,000 mile (58,000 km) warranty. The power train, restraint systems, and corrosion damage are covered for 60 months/60,000 miles (97,000 km). The hybrid vehicle system (the battery, motor/generator, advanced control system, etc.) is covered for 96 months/100,000 miles (160,000 km). Toyota also offers free roadside assistance (including flat tires), available through a toll-free call. Routine maintenance is recommended at 7,500 mile (12,000 km) intervals.

Good Ride

Driving the Prius is like driving any other modern car, except for six things that I've noticed:

- The engine starts after releasing the key. You don't crank it until it starts (It's too quiet to hear anyway).
- The shifting mechanism is best described as a stick shift lever sticking out of the dash. The two-speed automatic transmission is labeled the usual "D" for drive, but low is labeled "B" for braking. When downshifting down a steep hill, regenerative braking puts more energy back into the battery.
- The ABS regenerative brakes can have the slightest sensation of grabbing while applying foot pressure. We've now gotten used to it and don't notice it.

- At a long wait at a stoplight, the engine may shut itself off to save fuel (no need to restart; just press the accelerator to continue).
- The dashboard lights and gauges are center-mounted in the dash where it meets the windshield, rather than in front of the steering wheel.
- A multifunction 4 by 6 inch (10 x 15 cm) display gives the driver feedback on fuel consumption, momentary hybrid power configuration, and radio frequency or CD track.

Mileage seems optimized at 45 to 55 mph (70–90 kph)—too slow for freeways and too fast for most city driving. Acceleration is adequate for entering freeways and passing. Toyota claims a maximum cruising speed of 105 mph (170 kph)—but I wouldn't (and won't ever) know about that.

Technical Details
So how does it work? A computer constantly monitors the demands on the vehicle and continuously reconfigures operation to minimize fuel use. The advanced control system (ACS) monitors grade steepness, battery charge, accelerator pedal, brakes, air conditioning, and engine speed, and then selects the optimal combination of power.

Depending on need, the ACS chooses between three options:

- Gasoline engine and electric motor/generator together for extra power;
- Gasoline engine off when coasting or standing still; or
- Electric motor/generator powered by the battery for cruising or accelerating. During deceleration, the computer activates regenerative braking power to recharge the battery.

Based on the amount of power needed, the gasoline engine is either powering the wheels (and/or the electric generator that is charging the battery) or it is off.

The electric motor/generator is either powering the wheels by itself or in concert with the gasoline engine, or it is generating excess power for storage in the battery. The electric motor/generator can be powered by either the battery or the gasoline engine.

When coasting or braking, the electric motor/generator acts as a generator and charges the battery. If the vehicle is stopped for long (such as waiting for a light), the gasoline engine shuts off. Pressing on the accelerator moves the car with the electric motor. As the vehicle decelerates, about 30 percent of the energy traditionally lost in braking is captured by the motor/generator and stored in the battery.

Idling & coasting: The engine uses the motor/generator to charge the battery.

Stopped: If the battery is full, the engine shuts off.

Heavy on the pedal: Power comes from both the engine and the motor/generator, drawing from the battery.

Medium on the pedal: Power comes from both the engine and the motor/generator, while charging the battery.

Light on the pedal: Power comes from the motor only, drawing from the battery.

Coasting or braking: Power comes from the wheels to charge the battery.

The LCD screen also displays cumulative and instantaneous fuel economy.

The upper screen shows low mpg while accelerating.

The lower image shows high mpg while coasting

When driving uphill, the gasoline engine splits its power between the wheels and the electric motor/generator that either sends power to the wheels or the battery for later use. When demand is high, the battery powers the electric motor/generator along with the gasoline engine to power the wheels. At highway speeds, the gasoline engine is the primary source of power, with the electric motor/generator assisting as necessary.

The hybrid system is designed to excel during city driving. I and other Prius owners I've consulted have not quite been able to achieve the 52 mpg EPA rating for city driving. My experience has been more like 46 to 50 mpg. But I live in a relatively small town that doesn't have many traffic jams. In serious stop-and-go traffic, the fuel economy may be better. The ACS is programmed to minimize gasoline consumption by relying on the electric motor/generator powered by the battery as much as possible. At low speeds, the gasoline engine comes on only to assist with acceleration or to charge the battery.

The permanent magnet electric motor (which doubles as a generator to store power in the battery that otherwise would go to waste) produces a maximum of 44 horsepower (33 KW). The 70 horsepower gasoline engine is a 4 cylinder, 16 valve, 1.5 liter double overhead cam that features variable valve timing to improve mid-range torque for passing, to maximize fuel economy, and to lessen emissions.

The battery was developed with Panasonic. It consists of 38 sealed, nickel-metal-hydride (NiMH) modules, weighing 110 pounds (50 kg) total, and is designed for tens of thousands of charges. For safety, the battery is completely sealed in a carbon composite case and is positioned behind the rear seat. Toyota claims that the hybrid battery doesn't emit an electric or magnetic field. The 273.6 volt battery (228, 1.2 volt cells) isn't something to mess around with.

The traction battery is small because it doesn't have to contain all the energy to power the vehicle. Its purposes are to capture wasted energy while the gasoline engine is running, to recapture some of the energy normally lost during braking, and to assist acceleration.

The lights and accessories run on a traditional 12 volt system. The 12 volt accessory battery is accessible through a cover panel in the trunk. You can run this battery down just like a regular car battery, and you can jump-start the car just like any other car.

Design Details

While the hybrid power system and the regenerative braking have made the most news, the Prius is also better designed, engineered, and constructed to minimize fuel consumption. Several little things add up:

- The floor and roof are insulated to reduce the load on the air conditioner. The side and rear windows block out an additional 13 percent of unwanted ultraviolet rays, helping keep the cabin cool.
- The wheels are ultralightweight aluminum, and the tires are a special low rolling resistance design.
- Better aerodynamic shaping helps cheat the wind by causing less drag. A flat underbelly creates less turbulence. The sleek shape, combined with the rear spoiler, results in a sports car-like 0.29 coefficient of drag, like the new Toyota Celica.
- A two-level air conditioning system improves efficiency and thereby reduces the air conditioning demand on the power system. It's also CFC free, giving the ozone layer a break.

As with the ACS system, all this efficiency occurs without the user being involved.

Use & Service

The "energy" display on the in-dash liquid crystal screen graphically represents what's going on under the hood—for the education and entertainment of the humans onboard. One touch away, the "consumption" screen displays cumulative and current fuel efficiency, along with the average fuel efficiency for the last six, five-minute intervals. You can easily comprehend how fuel use changes as you slowly leave the garage, snake through the city streets, and accelerate onto the freeway. Bright yellow icons denote each 50 watt-hours of energy "recovered."

Don't even think about servicing this vehicle yourself. Yes, you can fill the window washer fluid and maybe even change the oil, but you don't want to mess with the computerized propulsion system. And tempting as it may seem, you can't power the car solely on the storage battery after running out of gas.

This is a highway vehicle with only a 4.9 inch (12 cm) road clearance. It is a comfortable ride, but it's not designed for driving on ungraded roads. Since it runs on gasoline, fueling is not an issue as with a pure electric (or biodiesel) vehicle, because gasoline is readily available at local service stations.

There are other perks besides driving the least brown (I wouldn't say "greenest") car now widely available. At least two states (Oregon and Maryland) offer US$1,500 tax credits for purchasing a Prius. In Virginia, you can drive solo in the high-occupancy vehicle lane if you have special plates.

The author is happy with his car, its performance, and its message.

Toyota estimates that the Prius costs US$35,000 to produce, and reports that the company is low-balling to gain market share. (The actual cost of production is a function of how many it sells.) Also, such a low-pollution vehicle helps Toyota meet the corporate average fleet efficiency (CAFE) standards required by the U.S. Clean Air Act, by mitigating the sale of gas-guzzling, sport utility vehicles.

Toyota sees the writing on the wall. The traditional internal combustion engine is on its way out. The Toyota Prius is a transition step that optimizes the efficiency of such an engine.

If gas prices continue to rise (even though in real cost terms, gasoline is about as cheap as it has ever been), you may be able to economically rationalize additional cost through anticipated fuel cost savings. It depends on how much you are spending on fuel annually.

The manufacturer's suggested retail price (MSRP) for the Prius is US$19,850. Demand is greater than supply, so don't expect to bargain. The straight gasoline Toyota counterpart is the Echo, a dead ringer for the Prius, save for no rear spoiler, with an MSRP of US$10,395. At today's fuel prices, you would have to drive a lot of miles (burn lots of gasoline) to economically rationalize the additional cost of the Prius over the Echo.

Assuming you are in the market for a new four-door sedan, the marginal additional cost of a Prius compared to an Echo is US$9,455, before any government rebates. Assuming you are "average" as defined by the EPA, and drive 15,000 miles (45% highway, 55% city) annually, the average annual fuel cost (US$1.70/gallon regular gas) will be US$525 for the Prius and US$754 for the Echo (31 mpg city, 38 mpg highway). Dividing this US$229 savings by the marginal cost difference yields a return on investment of 2.42 percent, tax free. If you drive more than the EPA average, you will save more money each year, increasing the return on investment rate.

A better rationalization is social and environmental in nature. Since the true cost of gasoline and its use are not rationally accounted for, you could get higher financial returns by investing your US$9,455 elsewhere. But if you buy a Prius, you're going to spend some extra money to do your part to reduce air pollution and global climate change.

What's it worth to you to not have the northern polar ice cap melt out from underneath the polar bears, or to not have penguins dying of heat stroke? To not have several island nations flooded out of existence, along with much of the developed shoreline of the world? To not move the Corn Belt to northern Canada and tropical diseases to the continental United States? The gasoline-electric hybrid is an important transition step from the gasoline internal combustion engine to nonpolluting and sustainable propulsion systems of the future.

Access

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The author acknowledges the assistance of colleague and fellow Prius owner Bettina Von Hagen in the preparation of this article.

For more information on the Prius, see http://prius.toyota.com or your local Toyota dealer.

Renewable Energy and Sustainable Living Fair 2001

Eric Grisen

"There's no place like home!" was the theme of the 2001 fair. After last year in the big city of Madison, the fair was back at home in Amherst.

No other fair in the world is like this one. It's the only event where you can learn as much in three days, have as much fun doing it, and walk away with such a feeling of optimism and positive community. It's the Midwest Renewable Energy Association's Renewable Energy and Sustainable Living Fair!

The 12th annual Renewable Energy and Sustainable Living Fair was an unprecedented event of quality information, ethics, and entertainment. The fair is the largest and longest running, small-scale renewable energy (RE) education event in the world. More than 15,000 people from 49 states and 37 countries filled Amherst, Wisconsin's Portage County Fairgrounds for the three-day fair held on June 22–24, 2001.

Attendees were drawn by any number of attractions. They included celebrity keynote speakers, 160 vendors and exhibitors, 100 free workshops, solar home tours, organic foods, microbrews, evenings full of live music, inexpensive on-site camping, and a surprise wedding. Yes, a wedding!

Personally, I came with high expectations. This was my first time at the fair, and it had quite a reputation to live up to. I was looking to get some RE questions answered, meet the people who make and sell RE and sustainable living gear, soak up the unexpected, and have some fun. The program guide we received in the mail a few weeks before the fair boasted its goal as a "trash-free" event. So I brought my cup, plate, silverware, and an open mind.

Above: "So tell us again how this solar panel works." Fairgoers were able to get their RE questions answered by the experts.

Information Is Power

Energy fairs are the place to get all your questions about renewable energy answered. Many major manufacturers of photovoltaics (PVs), inverters, and wind generators attended the fair. There were also manufacturers and dealers of microhydro turbines, solar hot water systems, electric and hybrid vehicles, and energy efficient appliances. Many exhibitors were there with new technologies and products.

One of the products prominently displayed at the fair was the Proven downwind turbine, which has a 3.5 meter (11.5 foot) rotor diameter. It was hard to miss this 2.5 KW wind generator, since it was spinning on a large, freestanding tower in the middle of the fairgrounds. It was installed as part of a prefair workshop a few days before the gates opened.

Wind machines, wind machines; everywhere you looked there were wind machines at this fair! Shown are LoTec's restored water pumping windmill and Proven's wind generator.

"Hey, check this bird out. Looks pretty simple. Betcha I could build something like this. How does it work again?" A close-up view of the Proven downwind turbine without its shroud.

The Proven machine has been manufactured by a Scottish family business for the past fifteen years. Its unique downwind design, large swept area, and heavy construction keep the machine cranking. Under high wind loads, the blades fold into a cone—like an octopus pulling all of its legs together. Although winds were fairly light at the fair, the Proven quietly worked hard all three days, generating interest as well as electricity.

In addition to commercial booths, nonprofit informational, educational, and activist groups had a strong presence at the fair. They balanced out the technological and commercial information nicely. Among them was Nukewatch, a watchdog group helping to protect against the proliferation of nuclear weapons and waste contamination.

Powerful Speakers

Two environmental heroes of our time graced this year's keynote platform. Julia Butterfly Hill and Captain Paul Watson spoke to overflowing crowds. Their stories of dedication and sacrifice set a positive tone of conservation, action, and love at this year's fair.

Julia Butterfly Hill brought the preservation of old-growth redwood trees into the media's world spotlight two years ago after her epic, two year long tree-sit. She is founder of the Circle of Life Foundation, and the author of *The Legacy of Luna*. She made her stand against Pacific Lumber Co. from 180 feet (55 m) above ground in a thousand-year-old redwood tree named "Luna." Her actions resulted in the preservation of Luna and the surrounding redwood trees.

During her months of action, Julia focused on keeping love in her heart despite the extreme hardships she endured. She came close to death on numerous occasions at the hand of her opponents and severe winter storms. Her message at the fair was to keep love central in your heart. Love makes any action possible.

Captain Paul Watson is co-founder of the Greenpeace Foundation, founder of Sea Shepherd Conservation Society, and author of numerous books including *Earthforce!: An Earth Warrior's Guide to Strategy*. He is called radical for his confrontational tactics to enforce international and United Nation environmental laws that are knowingly and persistently disregarded.

Watson and his crews use extreme measures, which have included sinking eight illegal whaling ships and ramming numerous other pirate vessels. As a result of his actions, he's saved the lives of tens of thousands of whales, hundreds of thousands of dolphins, millions of seals, and hundreds of wolves.

Despite his aggressive approach, Captain Watson boasts that, "these things were accomplished without causing or sustaining a single injury to our opposition and crew. Additionally, these missions did not result in a single criminal or civil conviction against me, my society, or my crew." His message to the crowd was to set a high standard of ethics to live by, and dedicate your life to upholding them.

Julia Butterfly Hill, Saturday's keynote speaker, addressed an overflowing crowd of fairgoers.

Rural Renewable Energy Alliance—helping folks make sustainable choices for the future.

AstroPower exhibiting its photovoltaic modules.

Cliff Millsapps demonstrates how the Solar Pathfinder can evaluate a site's solar potential.

Another was the Sierra Club, representing its powerful conservation organization of 650,000 members.

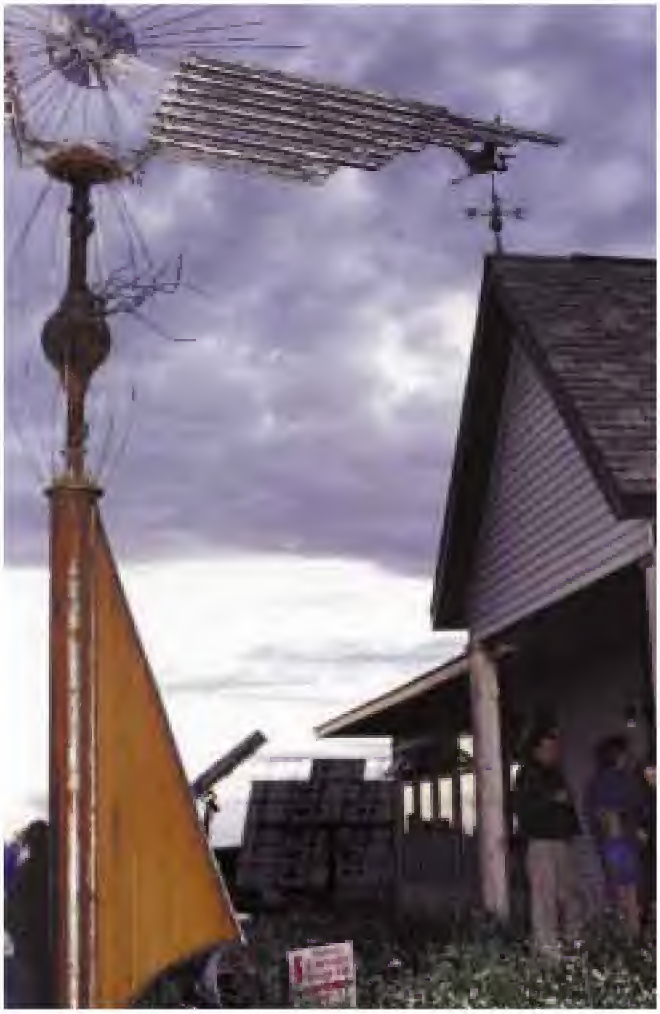
The local RENEW Wisconsin booth was promoting consumer participation in accelerated green power programs and RE project facilitation. Wisconsin's local Earth First! was also there educating folks about the dangers of genetically engineered foods, and advocating its "no compromise" policy in defense of Mother Earth.

Workshops

In the shade and yellow glow provided by the eleven large circus tents, fairgoers were given the opportunity to attend any number of the 100 free workshops. The workshops are led by experts and pioneers in their fields. It was truly a unique learning opportunity for beginning to advanced participants.

In his inverter workshop, Richard Perez discussed inverter topologies, waveforms, and tech specs.

Many of the workshops were scheduled multiple times, so it was possible to catch them on another day if you were busy. Subjects included basic electricity and energy, photovoltaics, batteries, inverters, the grid, wind systems, green building materials, energy efficiency, space heating and cooling, transportation and fuels, socially responsible business and finance, as well as fun workshops and entertainment for kids and families. Most of the workshops were heavily attended.



Beauty and function—ReNew the Earth Institute.

ReNew the Earth Institute

Just a short bus ride away from the fair, near the town of Custer, is a living example of sustainable living ethics. ReNew the Earth Institute (REI) is the Midwest Renewable Energy Association's (MREA) showcase of many RE technologies. Tours to REI were included in the solar home tours that departed from the fair each day. Visitors saw renewable energy in action!

The passive solar building sits on five acres of gorgeous farmland, against a backdrop of towering conifer trees. Above the trees is a 3.6 KW Jacobs wind system on a 100 foot (30 m) freestanding tower. To the east of the institute, a crop of PVs follow the sun and help contribute to the building's grid-tied RE system. The building is heated with solar hot water and a masonry stove.

This awesome facility may host a future fair. There has been discussion among fair organizers and board members about moving the fair to this site. Some MREA supporters would like to see this idea through to fruition.

"I now pronounce you husband and wife—you crazy kids."

The Scene

This report would not be complete without at least a brief mention of the fine indulgences and entertainment the fair offered. Food choices ranged from organic vegetarian burritos to organic bratwursts, Native American fry bread creations to salads, with ice cream and chocolate for dessert.

The beer garden and music venue raged both nights with two great bands. Friday night's stage was filled with about ten talented musicians called Irene's Garden. Their original punk, reggae, and R&B sounds had most people dancing. Then on Saturday night, Baba Ghanooj kept the crowd rockin' into the night as well. Away from the main stage and into the on-site camping area, the scene was a little mellower—except if you were around Home Power's camp...

Wedding Celebration

Congratulations to Kelly Olson and Bob Cornett, who were married at the fair on the afternoon of Sunday, July 26, 2001. The beaming couple exchanged vows

Congratulations to Kelly and Bob Cornett!

under the shadow of the fair's PVs and wind generators.

Bob is a social worker and community gardener, and Kelly is a biology student and MREA volunteer. Kelly and Bob have made their home in Ashland, Wisconsin, and they want to, "deck it with renewables." MREA Executive Director Tehri Parker officiated at the ceremony, which was witnessed by family, friends, and curious fairgoers.

Thanks MREA!

The fair experience did not fall short of my expectations. I won't think twice about making the pilgrimage from Oregon to Wisconsin again next year. My experience was informative, fun, challenging, and entertaining. If you didn't get a chance to attend the 12th annual Renewable Energy and Sustainable Living Fair, I recommend that you come and check it out for yourself next year.

Access

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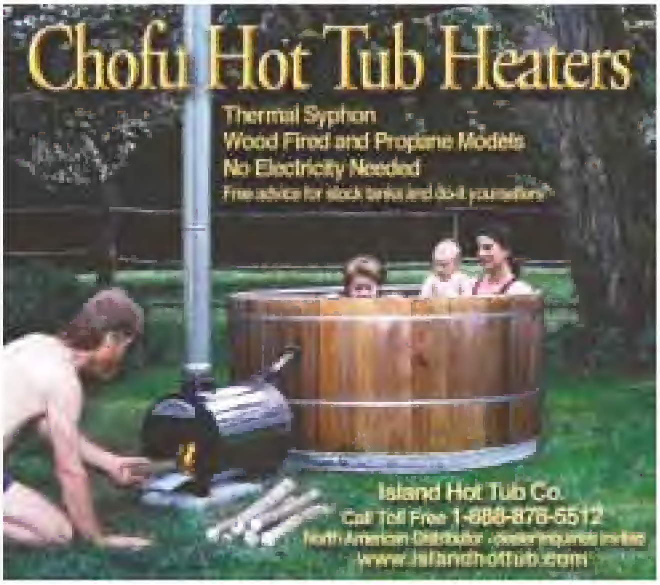

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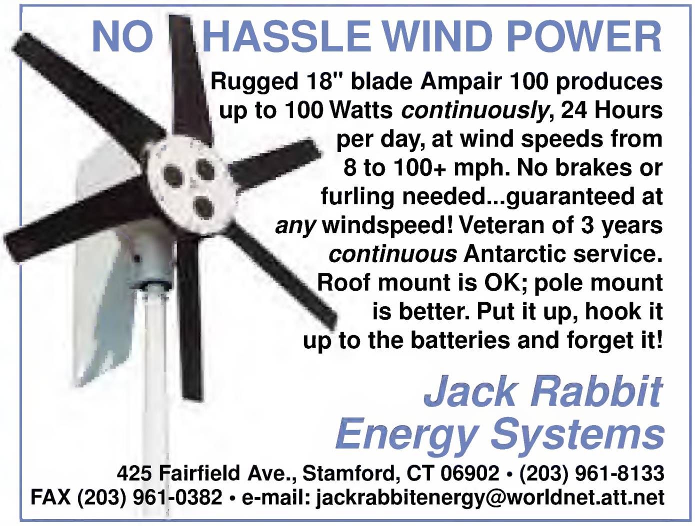

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Water-Powered PV Tracker

The author's water-powered PV tracker.

Photovoltaic panels produce the most energy when oriented perpendicular to the sun. So a panel mount that follows the sun's arc can increase daily output by up to 50 percent in summer, and up to 20 percent in winter, when the sun moves through a smaller arc. Of course, the degree of benefit depends on how much unobstructed sun exposure a site has throughout the day. Seven or eight hours is enough to make tracking pay off.

I am fortunate to have more than twelve hours of sun exposure throughout the hottest summer months. This is when I need to pump the most water. So a tracking mount was an obvious choice to maximize benefit from my investment in a solar submersible pump and PV panels.

Tracking Sense

Tracking can make economic sense by allowing you to meet your energy needs with smaller, less expensive PV panels, compared to higher wattage panels on a fixed mount. In addition, low-producing wells can benefit from tracking for another reason. These wells have a slow recovery time. The water level in the well returns slowly after fast pumping, requiring intermittent pumping to avoid running the pump dry. In many cases, tracking allows you to run a low-volume pump all day long without pumping the well dry. This yields more water than a higher output pump operating fewer hours per day.

I knew that commercially made trackers were available, including passive, freon-actuated trackers and active electric-powered models. But having the homebrew bug and more time than money, I opted for the simplicity and low cost of my own water-weight-driven system.

This is the second water-powered tracking system I have built. I first came up with the idea several years ago after installing my first solar powered pumping system on another, very low-producing well. I mounted a single 50 watt PV panel on a fixed mount, figuring this low-powered setup would approximately match the well's low water production. The well turned out to produce more water than the solar-electric system could extract each day. So I looked at using a tracking mount to boost pump output.

I felt that commercial trackers were too expensive to justify for this particular use. I knew though, that the commercial passive trackers rotate via the shifting weight of freon as it boils from a sun-heated container and recondenses in a shaded one on the other side of the unit. Being a do-it-yourself kind of guy, I looked at what driving forces I had available at this well site, and the answer was obvious—water!

Homebrew Tracker

I built the tracking PV mount detailed here for two tower-mounted, 75 watt panels that power a Shurflo, solar submersible well pump. The water is used for my primary household supply, as well as for drip irrigation of 200 apricot and plum trees. In this particular installation, the water is pumped to a storage tank 40 feet (12 m) higher than ground level at the tower—65 feet (20 m) higher than the water level in the well. The tank supply line ran close to the PV tower, so I had gravity-fed water pressure available to power the tracker.

My system is simple. A battery-powered irrigation timer adds water to a bucket during the day, increasing the bucket's weight. Through a rope and pulley system, the bucket gradually rotates the panels westward. A separate timer drains the bucket after dark and allows return springs to rotate the panels back to the east again. The timers use two ordinary C-cells, which last six months to a year.

This system is inexpensive, simple to set up, and very effective. It consumes only 3 gallons (11 l) of water per day, which drains onto a tree after dark. Together with a linear current booster (LCB), this system vastly increases the volume of water I can pump compared to a fixed panel mount. An LCB matches the solar array's peak power point to the voltage and current requirements of a loaded motor. The results are more power to overcome motor start-up surge, and greatly increased motor performance in low light conditions. In late April, my pump operates from 7 AM to 7 PM, lifting 1,400 gallons (5,300 l) 65 feet (20 m) in twelve hours.

The pivoting assembly with two PV panels bolted to angle iron crosspieces and aluminum cross bracing. Note the pivot points on the outer angle irons, and the half-bicycle rim mounted to the center angle iron.

This is a close-up of one of the pivot points—a piece of flat stock welded to the angle iron. It is bolted to the fixed part of the mount with Teflon washers between the two parts to minimize friction.

Half of a 21 inch (53 cm) aluminum bike rim serves as an attachment point for two ropes. One rope applies spring tension to the panels to rotate them east, and the other applies the weight of the water bucket to pull them west.

The rim essentially acts as a pulley, allowing the ropes to apply force at a constant radius to the rotating panel assembly. Whereas the same ropes fastened directly to a point on the angle iron would also cause rotation, the angle of pull would change with the rotation, making things a bit more tricky to regulate.

The panel assembly rotates on this fixed part of the mount. It pivots on bolts through the tops of the triangles. The two lower struts are manually moved up or down the central mast to change the north/south tilt seasonally. The central mast inserts into a socket at the top of my tower.

The top end of the fixed part of the mount pivots for the north/south adjustments. It connects to the mast with a bolt through two brackets. Note the cross-piece attached with C-clamps. This piece is for attaching the pulley for the water bucket, and was temporarily attached with C-clamps at this point until the exact mounting location was determined after mounting to the tower.

A bottom view of the mount in place on the tower. The panels are in the morning position, facing 45 degrees east. The spring rope runs through a pulley on the right side of the frame, and then diagonally down to the springs, which fasten to the lower left corner.

There are two springs connected end to end, because I didn't happen to have a single one long enough. Then, a third spring is attached to a chain. The chain has slack at this point, so this third spring will not come into play until the midpoint of the panel rotation. This gives a progressive spring strength that is easy to calibrate to prevent over-rotation in the afternoon. The bucket rope is not visible in this view.

Water-Powered Tracker Costs

Item	*Cost (US$)*
Nelson irrigation timer, battery powered, 4 times-per-day	$35
Angle iron, 1-1/2 x 1-1/2 x 3/16 inch	25
Irrigation timer, battery powered, 1 time-per-day	20
Misc. plumbing & drip line fittings	20
Angle iron, 1 x 1 x 1/8 inch	15
Misc. bolts, pulleys, rope, & springs	12
Aluminum angle iron, 1 x 1 x 1/8 inch, reinforcing for panels	6
Steel for the tower, salvaged free	0
Total	$133

A bottom, west side view of the mount in the midday position. The third spring is now under tension, and will prevent over-rotation in the afternoon. The bucket rope is visible here, passing through a pulley in the center of the crosspiece, and then down to the bucket, which hangs in the center of the tower. Between the top pulley and the bucket, the rope passes through a couple of brackets with slick plastic guide holes to prevent the bucket from swaying in wind.

The bucket, a 5 gallon (19 l) oil pail, has a male hose-end fitting installed in the bottom and a small drip irrigation fitting in the top for an air vent. The metal box below houses the irrigation timers and wiring.

I have observed that by tracking the PVs, the pump runs for about thirteen hours a day in mid-June, 6:45 AM to 7:45 PM. Without tracking (mount fixed due south), pumping hours are 9 AM to 6:15 PM. Aside from the extended pumping hours, the pumping is much stronger early and late in the day with the tracker.

A close-up of the control box. The copper pipe supplies water from the nearby storage tank supply line to a Nelson battery-powered irrigation timer. This particular timer has up to four watering intervals per day, but other models have six. 1/4 inch (6 mm) drip irrigation tubing runs from the timer output to the fitting on the bottom of the bucket.

A tee in the line just below the timer runs to the drain timer, a simpler model with only one interval per day. The drain timer output is a female hose-end/female pipe fitting connecting to a male pipe/male hose fitting passing through the box. This mounts the drain timer to the box, and provides a hose-end fitting on the bottom of the box to attach the bucket drain hose.

The fill timer runs three minutes at 10:30 AM, and then one minute each at 11:30 AM, 2 PM, and 3:30 PM. The drain timer runs for fifteen minutes at 8:30 PM. These times can of course be easily changed seasonally as necessary. The well pump's linear current booster (LCB) is seen behind the open junction box.

Regulating the tracking is quite simple because there are several ways to change it: spring strengths, spring preloads, timing of the secondary spring force, and bucket fill times and durations. I made very few changes beyond my initial guestimations to fine tune it.

Improvements to This System

In hindsight, I could have made a couple of improvements. First of all, I would suggest placing the panel pivot points in line with the center of gravity of the panels, rather than below that point, as I have done. This would make them weight neutral, instead of wanting to fall to the right or left, regardless of rotational position. Making this change would require making the stationary part of the mount slightly longer than the panels. The pivot points could then be directly off the ends of the panels, at or just below the panel glazing. This would further simplify regulation of the spring and bucket forces.

You could also easily increase the panel travel well beyond the 90 degree rotation that I have used. To do this, the bicycle wheel "pulley" would need to be a complete circle mounted on the end of a pivot shaft coming off one end of the panels, rather than the half wheel underneath the panels.

I should have put the mast-end (north/south) pivot nearer the center of the panel length and higher up in the stationary "pyramid," rather than low and close to the top end as I have done. This would balance the weight better, and simplify relocating the struts when making seasonal changes.

My system is quite heavy, and all the weight is cantilevered off the front of the mast. It's a strain to remove the struts from their mounting bolts on the mast and move them to new positions.

Water-Powered Tracking

I am delighted with the way this system works. It tracks very consistently, and seems unaffected by wind. Best of all, it just seems somewhat akin to perpetual motion to have PV panels following the sun by virtue of water pressure that those same panels produce.

Access

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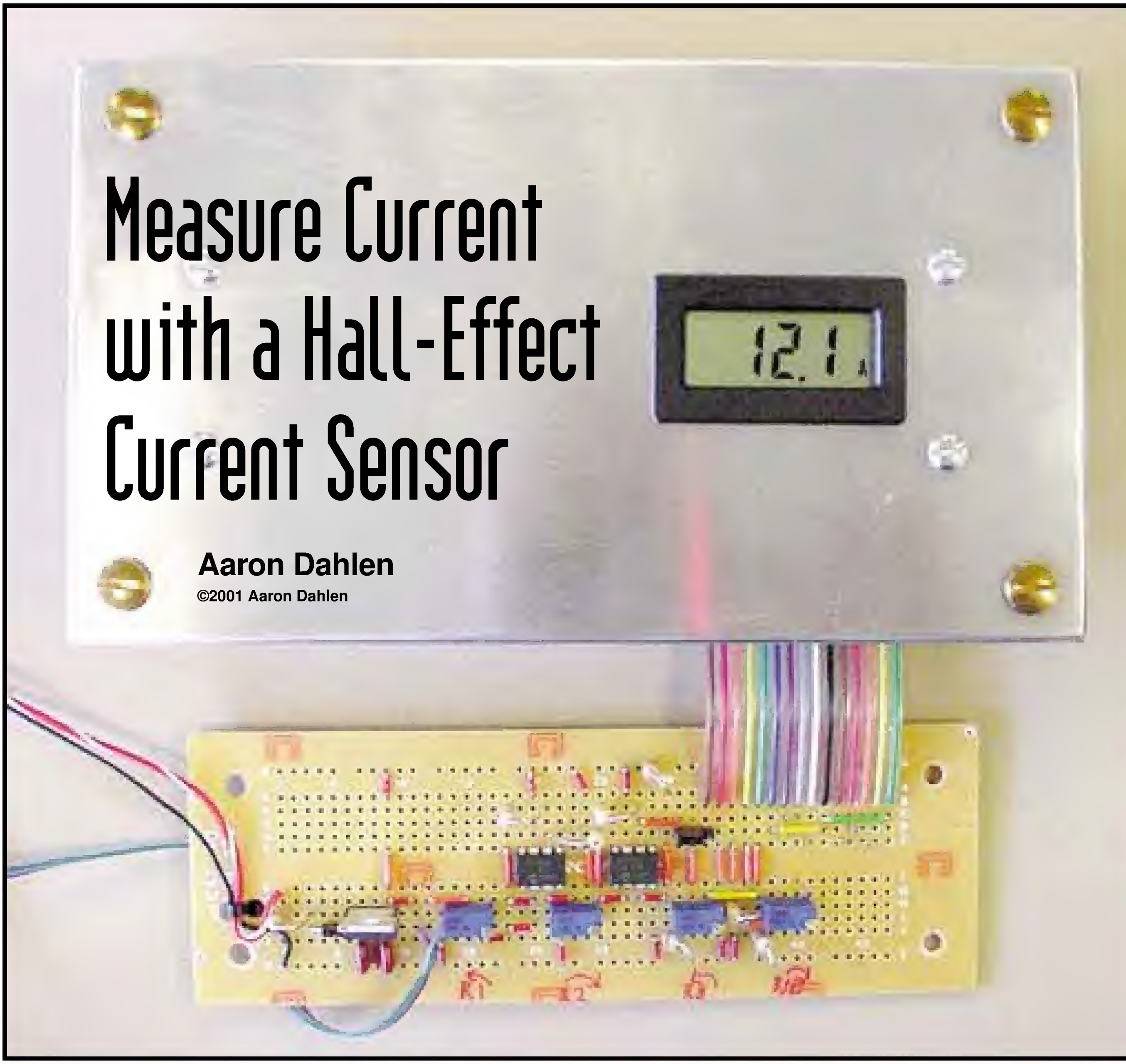
Measure Current with a Hall-Effect Current Sensor

Aaron Dahlen



Amazing and fun! These are words I use to describe Hall-effect sensors. You probably already own several of them. Automobiles use them to detect speed and relative location of rotating parts. Hall-effect sensors are also finding their way into consumer electronics. In fact, almost any application that requires a long-lived switch can use them. This article presents a circuit that uses a Hall-effect sensor to measure DC currents up to 200 amps.

A Hall-effect sensor is a magnetic field detector. A standard Hall-effect sensor acts like a simple switch. In the presence of a southern magnetic field, it turns on; with no magnetic field or a northern field, it turns off (N and S sensitivity is dependent on which side of the sensor the magnet is on).

Unlike a mechanical switch, the Hall-effect sensor has no moving parts. There is nothing to wear out or collect dirt. The fact that Hall-effect sensors are found in the engine compartments of automobiles attests to their durability.

Hall-effect sensors also come in the linear variety. A linear sensor responds to the intensity of a magnetic field. As a magnet comes closer to a linear Hall-effect sensor, its output rises; as the magnet moves away, its output decreases.

Close-up of the Hall-effect sensor and stabilizer capacitor. A major advantage of the Hall-effect current sensor is its isolation. It may be placed on either the positive or negative line. It is shown here measuring current in a positive line.

Magnets & Wires

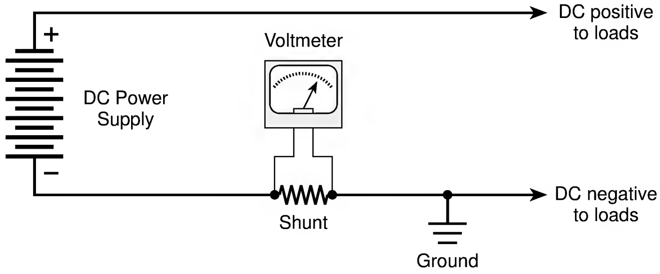
Electricity and magnetism are closely related—you could say one doesn't exist without the other. Electrons flowing in a wire will cause that wire to have a magnetic field. A linear Hall-effect sensor placed near this wire will respond to the intensity of the magnetic field. As the field grows (current increases), so does the output of the Hall-effect sensor. The linear Hall-effect sensor acts as an accurate current sensor.

The Old: Shunt Ammeters

The current measurement system in a typical DC system consists of two parts—a meter and a shunt. The meter is mounted in a location that's convenient to the operator. The shunt is installed in the circuit between the battery and the load.

A shunt is a small-value, precision resistor. A typical 100 amp shunt will have a resistance of 0.001 ohms. If 100 amps is flowing through it, it will have a voltage drop of 100 mV. The meter measures this voltage drop and displays it as 100 A.

Measuring Amperage with a Shunt



The shunt-style voltage meter is a tried and true technology. It is simple and reliable, but it does have some limitations:

- Lack of isolation—a shunt resistor and meter are part of the main battery circuit. For safety, they are usually placed in the negative side of the circuit. Little current will flow if the shunt becomes shorted to ground. Care must be taken not to short out both sides of the shunt, or else the current meter will not read correctly.
- Power dissipation—when a shunt resistor is used to measure current, you are actually measuring the voltage drop across the resistor. By definition, you are burning up valuable power. If 100 amps is flowing through the 0.001 ohm shunt, 5 watts of valuable power is wasted.

The New: Hall-Effect Sensors

The circuit presented in this article has none of these deficiencies. The Hall-effect current sensor has no electrical connection with the circuit under measurement. The sensor circuitry uses only 15 mA (0.2 W at 12 VDC) while performing measurements, and can be turned off when not in use.

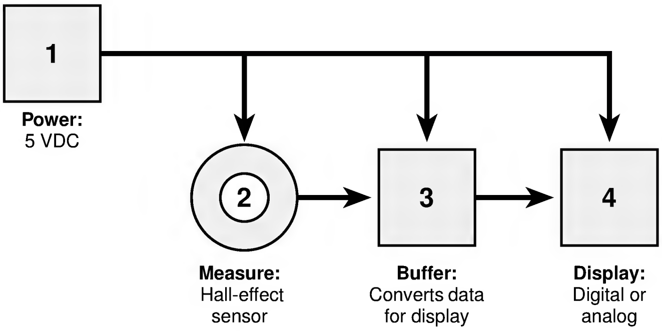
An Amploc linear Hall-effect sensor forms the heart of this project. Data sheets are available at www.ampsense.com. This project works with Amploc's XL, Pro, or Snap Clamp series of sensors. You can select a 5 to 200 A sensor to fit your application.

The current sensor is easy to install. Simply take the wire whose current you want to measure, and pass it through the aperture of the sensor. The Snap Clamp sensor is especially easy to use since you don't have to break any wire connections to install it. You simply assemble it over the wire.

This project consists of four major blocks as shown in the diagram below:

1. Power: A 7805 voltage regulator provides the required regulated +5 VDC to each block.
2. Measure: An Amploc current sensor performs the actual measurements. XL, Pro, or Snap Clamp current sensors may be used. The Amploc current

Hall-Effect Ammeter Block Diagram



sensors have a quiescent (offset or zero current) voltage of about 2.5 VDC. Using the XL100 as an example, the quiescent voltage is 2.5 VDC. If the sensor is measuring 100 amps, its output voltage will rise to 4.6 VDC. Watch out for the direction of current flow! The 2.5 to 4.6 VDC voltage range is true only if current is flowing in the direction of the arrow located on the current sensor.

3. Buffer: The buffer takes this raw voltage (current data) and converts it to a 0 to 5 VDC output. The 0 to 5 VDC full scale was chosen to make calibration of the display easier.
4. Display: A Red Lion Controls display was used for this project. The display is simple, easy to use, and relatively inexpensive. As an alternative, an analog meter could be used. The photo at right shows the circuit in operation using an analog meter that I salvaged out of an old transmitter.

Theory of Operation
Refer to the circuit schematic on the opposite page. Voltage regulator U3 provides a regulated +5 VDC to all circuits. Capacitors C2 and C3 stabilize the circuit. Diode D1 and resistor R12 provide polarity and short circuit protection. The sensor is a Hall-effect current sensor. Its output is proportional to the current flow in a wire that passes through its aperture. The sensor requires a regulated +5 VDC. Capacitor C1 stabilizes the sensor. C1 should be placed as close to the sensor as possible.

The amplifiers U1 and U2 take the raw, 2.5 to 4.6 VDC input from the current sensor and convert it to 0 to 5 VDC. Resistor R1 adjusts the gain of the amplifier. Resistor R2 removes the DC offset (2.5 VDC) of the sensor. U1 is an inverting amplifier. The ratio of R1 to R3 sets circuit voltage gain. U2 is a unity gain inverting buffer amplifier. Resistors R5 and R6 provide a 2.5 VDC reference to the noninverting input of U2. The output of U2 will be between 0 to 5 VDC. The Microchip MCP601 operational amplifier was chosen for this application because of its superior operation in a low voltage environment.

Close-up of the completed unit, face down.

An analog meter may be used in place of the digital display.

Switch S1 is used to calibrate the display. In normal mode, S1 passes the output of U2 to the display. When S1 is in the calibrate position, +5 VDC is passed to the display. Resistor R8 is adjusted so that the display indicates full deflection. If a 100 amp sensor is used, R8 is adjusted until 100 A is read on the meter.

A Red Lion MDMV display was chosen for this application. The display requires +5 VDC to operate. It draws less than 1.0 mA, making it ideal for this project. The display measures DC voltages from 0.00 to 199.99 mV. Resistors R8 and R9 step the 0 to 5 VDC output of U2 down to this low level. Resistors R10 and R11 are used to zero the meter.

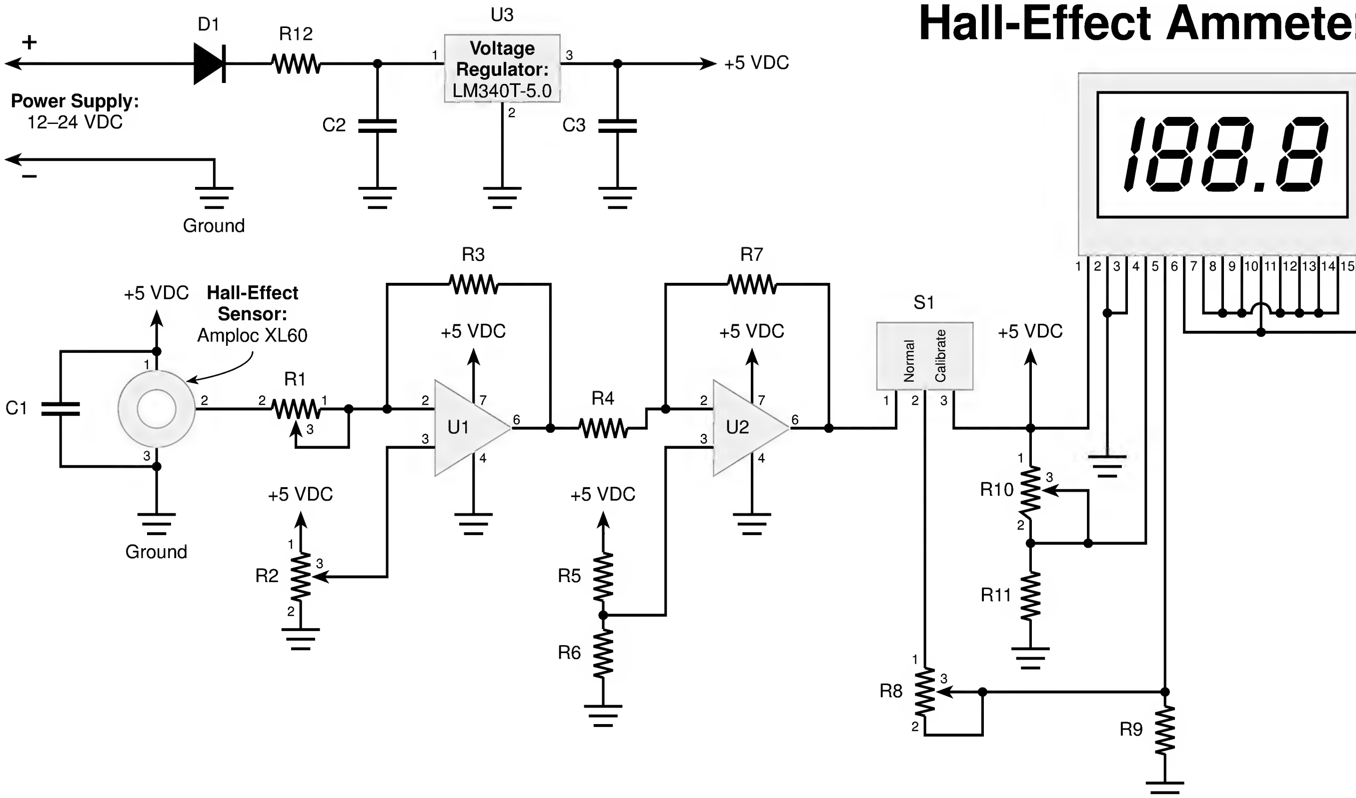
Calibration
There are two ways to calibrate this circuit. The best way is to compare it to a known, accurate ammeter. Insert the ammeter in series with the circuit you want to measure. Adjust the Hall-effect circuit until it is accurate.

Second best is to calibrate it by sampling a known current. This is an exercise in Ohm's law. If you know the voltage and the resistance of a load resistor, you can determine the current. A 1.0 ohm resistor makes the math easy (if R = 1.0, voltage and current are equal). Remember, whatever you use, to make sure that it can dissipate the power. My "little" 225 W resistor tried to melt its way through my workbench!

Materials required for calibration:

- Calibrated voltmeter
- Two 12 VDC batteries
- 225 W, 1.0 ohm resistor or suitable high power substitute
- Miscellaneous wire

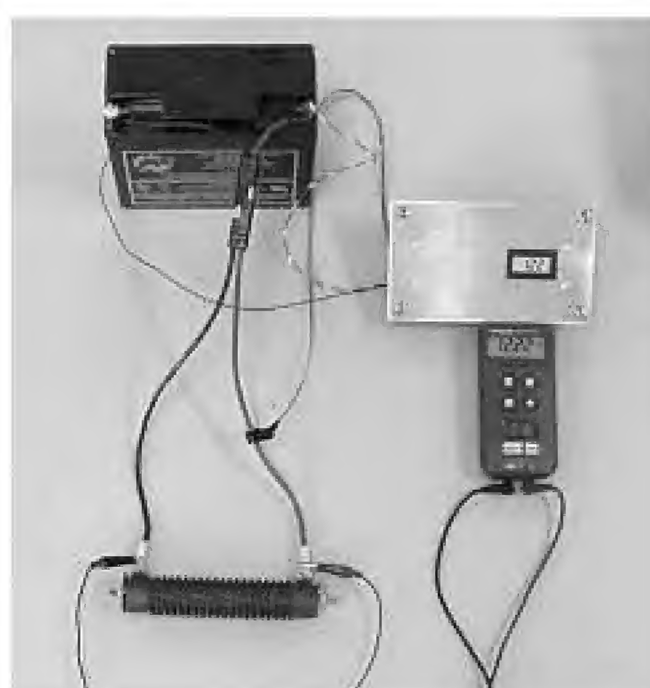
Hall-Effect Ammeter

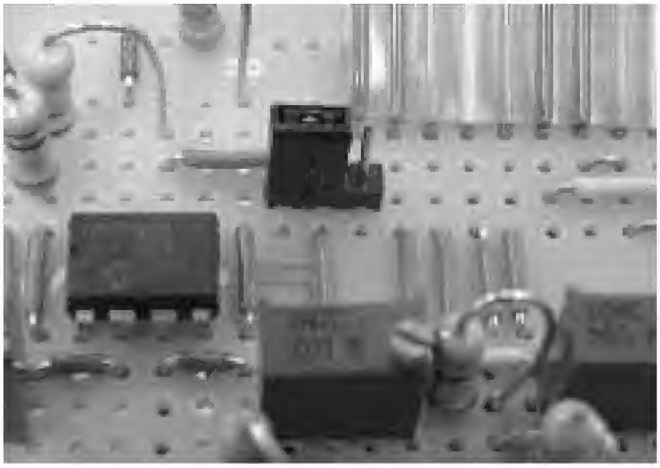


Calibration Procedure

1. With S1 in the normal mode, turn R2 until the display reads its minimum voltage.
2. Turn R2 an additional turn to be absolutely sure that the display is set to minimum.
3. Turn R10 until the display's negative indicator turns on.
4. Set R10 so that the negative indicator just extinguishes.
5. Place S1 in the calibrate position.
6. Adjust R8 until the display reads 100.0 amps (or maximum rating of your current sensor).
7. Place S1 back to the normal position.
8. With no current flowing through the sensor, adjust R2 until the voltage displayed on the meter just turns to 0.00 VDC. Verify by moving R2 back and forth.
9. Configure a setup as shown in the photo at right. (Do *not* make and break connections at the battery. A spark could cause the batteries to explode.) Be forewarned, the 225 W resistor is a bit on the small side. It will get very hot after a few minutes—hot enough to melt or burn its way through anything other than metal.
10. Measure the voltage across the resistor. Since a 1.0 ohm resistor is used, voltage and current are equal. Remember to scale your results if you use a different value resistor.

Calibration using a 1.0 ohm, 225 watt resistor (lower left) and a calibrated voltmeter (lower right).





S1 consists of a three-pin header and a shunt. Shown in the "normal" position.

11. Break the circuit at the resistor.
12. Adjust R1 to increase or decrease the current.
13. Repeat steps 8 through 12 to verify calibration. Resistors R1 and R2 interact with each other. When I calibrated the circuit, I had to repeat the steps more than ten times.
14. Verify calibration at higher currents using two batteries in series. Be quick! At 24 VDC, you are dissipating 576 W in the resistor. "It gets hot" is an understatement!

Putting It All Together
Circuit construction is simple and straightforward. I used the same method of construction described in my article in *HP83*. The circuit was first breadboarded and tested on a Radio Shack breadboard. After I was satisfied with its operation, I copied the circuit to a matching circuit card.

Be cautious with the display and MCP601 op-amps at U1 and U2. Neither will tolerate more than 6 VDC on their power supply inputs. A misconnected wire or accident with U3 (+5 VDC regulator) will be costly.

The circuit presented in this article will perform current measurements in a DC system. Its accuracy is equal to that of a mechanical meter. Just like a mechanical meter, it is most accurate in the middle of its range.

This circuit could easily be modified to display both voltage and current. A switch and two scaling resistors (similar to R8 and R9) are all that is required. If you want to be really fancy, you could make the annunciators (V, A, and W) of the display change with the switch.

An analog meter may be used instead of the Red Lion display. Connect the positive lead of the meter to the junction of R8 and R9, and the negative lead to the junction of resistors R10 and R11. Almost any analog meter may be used for this application. However, you may first have to modify the meter.

This can be a complicated operation. You must very carefully disassemble the meter. If the meter is a true current meter, the internal shunt resistor must be removed. If the meter is a direct reading voltmeter, the internal series resistor must be removed. Analog meters are deceptively complicated and delicate. Proceed carefully.

Hall-effect sensors are efficient, reliable, and inexpensive. This article presents a small fraction of what these devices can do. Refer to the Allegro and Amploc data sheets for more information. I hope you found this information useful. Please send me e-mail if you have any questions.

Hall-Effect Ammeter Parts List

Item	*Supplier*	*Part Number*	*Cost (US$)*
Display	Digi-Key	RCL-000	$35.90
Sensor	Amploc	XL60	16.90
Cable assembly for display	Digi-Key	RLC70	12.00
R2, R8: 10 KΩ pots	Digi-Key	3296W-103	5.00
R1, R10: 100 KΩ pots	Digi-Key	3296W-104	5.00
Circuit card	Radio Shack	276-170	2.99
C1, C2, C3: 0.068 µF	Digi-Key	P4523	1.77
U1, U2: Op-amp	Digi-Key	MCP601-I/P	1.36
U3: Voltage regulator	Digi-Key	LM340T-5.0 (7805)	0.90
D1: Rectifier diode	Digi-Key	1N4001	0.43
3-pin header: parts for S1	Digi-Key	WM4001	0.31
R3, R4, R7: 100 KΩ, 1/2 W	Digi-Key	Order by size	0.27
R5, R6: 10 KΩ, 1/2 W	Digi-Key	Order by size	0.27
R9: 51 Ω, 1/2 W	Digi-Key	Order by size	0.27
R11: 1.0 Ω, 1/2 W	Digi-Key	Order by size	0.27
R12: 100 Ω, 1/2 W	Digi-Key	Order by size	0.27
Post shunt: parts for S1	Digi-Key	A26228	0.09
		Total	$84.00

Access

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From Horsepower to Sunpower on the Mother Road

Shari Prange

Yesterday meets tomorrow as the solar car from Western Michigan University pulls into the Kingman, Arizona checkpoint.

Route 66. The name conjures up a slice of Americana that reaches beyond the borders of its own time and place. First, it was the Mother Road leading out of the Dust Bowl to the Promised Land of California. Soon, however, the journey itself became more important than any final destination.

Route 66 was an experience: Main Street, U.S.A., Norman Rockwell families, kitschy diners, and motor courts. Boys with ducktails, and girls with ponytails. The open road beckoning to adventure. You could get your kicks on Route 66.

And always cars. Hot cars, cool cars, fast cars. Woody wagons, primer painted rods, shiny 'vettes. If the automobile is the icon of an original American religion, Route 66 was the high temple. Over the years, however, Route 66 has been replaced, section by section, by newer four-lane divided highways. Many of its original twin lanes still exist, sometimes side-by-side with the newer four lanes.

This year, for the 75th anniversary of Route 66, a different kind of car rolled down the Mother Road. These cars were still shiny and beautiful, and very cool. But the throaty exhaust notes of yesterday have been replaced by silence. This time, the girl with the ponytail was as likely to be the one tinkering with and adjusting the motor. And she was thinking in kilowatt-hours instead of horsepower.

Some things don't change. Where there are cars, there are races. Instead of a roaring contest of acceleration and speed, however, this was a race of endurance and technology. It was the inaugural running of the American Solar Challenge.

The Rules

Transcontinental solar racing began in 1987 with the first World Solar Challenge across Australia. It was sponsored by GM, and (not surprisingly) was won by

the GM Sunraycer. The race has continued, and is being held in Australia again this year, although it is no longer sponsored by GM.

In 1990, GM launched the first Sunrayce, a solar endurance race for college teams, set in the United States. This race ran again in 1993, and then in alternate years through 1999, at which time GM withdrew from the program.

Now the Department of Energy and a handful of other sponsors and supporters are continuing the race in a slightly different form as the American Solar Challenge (ASC).

The same things that made Route 66 popular with truckers make it an ideal solar race route. Three of the teams ran the route last summer to test its feasibility. It had enough challenges to demand respect from participants, but it was mainly flat. The same sunny weather that truckers enjoyed across the American Southwest fueled these racers on their journey.

At nearly 2,300 miles (3,700 km), this was the longest transcontinental solar race ever. The daunting World Solar Challenge in Australia was less than 1,900 miles (3,060 km), and the most recent Sunracye in 1999, from Washington, D.C. to Orlando, Florida, covered only 1,300 miles (2,090 km).

The ASC race took place over ten days. Along the way, the cars stopped at fourteen checkpoints between the start and finish lines. The shortest interval between checkpoints was 107 miles (172 km) from St. Louis,

American Solar Challenge Race Results

Position	*Team*	*Car #*	*Class*	*Total Elapsed Time*	*Interval Miles Completed*
1	University of Michigan	2	O	56:10:46	2,247.39
2	University of Missouri, Rolla	42	O	57:30:52	2,247.39
3	University of Waterloo	24	O	62:00:18	2,247.39
4	Queen's University	100	O	62:55:11	2,247.39
5	Kansas State University	28	O	65:22:55	2,247.39
6	University of Minnesota	35	O	66:59:20	2,198.15
7	Principia College	32	O	67:25:43	2,247.39
8	Rose-Hulman Institute of Technology	74	O	69:17:30	2,247.31
9	University of Arizona	8	S	69:56:32	2,247.39
10	Massachussetts Institute of Technology	6	O	71:41:55	2,247.39
11	University of Missouri, Columbia	43	O	72:28:49	2,247.39
12	University of Toronto	1	O	79:08:57	2,247.39
13	Messiah College	77	O	80:22:37	2,247.39
14	South Bank University	41	O	80:44:47	2,247.39
15	Stanford University	16	S	90:58:16	2,207.20
16	Iowa State University	9	O	92:39:00	2,048.36
17	Association FUTURA	63	O	95:49:13	2,067.82
18	Stanford University	91	O	99:53:07	1,915.38
19	Minnesota State University	3	S	103:55:00	1,863.26
20	École de Technologie Supérieure	101	O	106:00:57	1,780.16
21	North Dakota State University	22	S	115:09:17	1,523.88
22	Los Altos High School / La Puente Valley ROP	11	O	121:41:50	1,602.66
23	Western Michigan University	295	S	125:08:49	1,425.05
24	University of North Dakota	0	S	127:17:35	1,023.82
25	University of Virginia	87	O	128:03:07	1,812.28
26	Northwestern University	150	S	130:04:09	1,164.33
27	Texas A&M University	12	O	130:31:11	1,194.48
28	University of Alberta	99	S	138:50:32	723.58
29	McMaster University	13	S	Withdrawn	90.10
30	University of Pennsylvania	17	O	Disqualified	90.10

Missouri, to Rolla, Missouri. The longest stretch was 228 miles (367 km) between Kingman, Arizona, and Barstow, California. These checkpoints doubled as public education displays.

Each racecar was also required to have both a lead and a chase vehicle. These helped maintain a safe flow of traffic around the racecar, and could provide assistance if there were any problems between checkpoints. The car could be trailered to the next checkpoint, but this would incur penalties against the team's overall performance in the race.

To make sure that the cars were capable of running the race, they were required to compete in one of two qualifying events held earlier in the year. These were held on closed race courses, rather than on public streets. Each car had to complete 125 miles (201 km), with a minimum average speed of 25 mph (40 kph) during a single 8-1/2 hour period. The teams did not have to run continuously, but could stop to rest the car and recharge the batteries from the solar panels.

The ASC race was different from the Sunrayces in several ways. One difference was that in previous races, cars collected at common checkpoints each night. They were timed for how long it took them to complete each leg of the journey. In the mornings, all the cars started together from the same point in what's called a staged start. The winner was the car with the least elapsed driving time at the finish line, which might not be the first car to physically cross the line.

In the ASC race, there were only three staged starts: at the beginning of the race, at the third checkpoint at the University of Missouri at Rolla, and at the last checkpoint at Barstow, California. In between, cars were required to make minimum stops at checkpoints, but could then continue driving until the 6 PM shutdown time each day. This meant that the field sometimes spread out over hundreds of miles.

"This made it harder, logistically, to keep track of everything," said spokesman Gary Schmitz from the National Renewable Energy Laboratory (NREL) of the sponsoring Department of Energy. "But it really added to the competitive nature of the race. This change was a great success."

An official race observer accompanied each car, and each car was equipped with a tracking unit supplied by Terion, one of the race sponsors. These units logged location and speed at fifteen-minute intervals. This information was then uploaded to the race Web site every hour, so that both race officials and the public could track each car's progress. At the finish line, the winner was the car that completed the course in the least driving time.

At 6 PM, they had to park for the night, but the cars were not impounded until 9 PM. This meant that the team could work on the cars, and make changes or repairs within the rules. Many also took the opportunity to remove the car's body and stand it up on an angle to catch the last rays of the sun and get a little more charge on the batteries.

From start to finish, the cars could not be charged from any other source than their solar-electric panels. If batteries failed, they could be replaced with new ones, but only at a significant time penalty, making this a last resort action.

The Cars

The cars looked nothing like any other kind of car—not a street car, nor any type of conventional racecar. Instead, most resembled either an elongated and flattened raindrop, or a padded envelope with rounded corners and a soap bubble rising from the middle. Some were more rounded, others more angular, but the majority represented some variation on these two themes.

The shapes were dictated, not by the rules of the race, which specified only maximum dimensions, but by the laws of physics. The long, flattened upper surface provided the maximum area for solar panels, while the gently curved teardrop shape minimized air resistance. To complicate matters, the designers also had to pay close attention to downforce. Otherwise, a strong gust of wind could cause the wing-like shape to take flight, since the cars only weighed a few hundred pounds each.

The cars could compete in either of two classes—Stock or Open. The Stock Class was intended to be affordable even for small schools and independent teams. ("Affordable" in this case means tens of thousands of dollars, whereas Open Class cars might cost hundreds of thousands.) For that reason, cars were limited to 165 kg (364 lbs.) of sealed lead-acid batteries. Their solar cells had to be purchased from an approved list of six specific modules, at no more than US$10 per watt for bare cells. This pretty much meant silicon cells in the 14 percent efficiency range.

With these restrictions, the cars were very closely matched for performance. How well the cars finished would depend largely on the reliability of the vehicle, and the smooth teamwork of the people, especially when solving problems and dealing with the unexpected.

The Open Class allowed different battery technologies, but each was limited by weight. While the cars could carry 165 kg (364 lbs.) of lead-acid batteries, they were limited to only 100 kg (220 lbs.) if they chose nickel

cadmium (NiCd), 60 kg (132 lbs.) for nickel metal hydride (NiMH), and 30 kg (66 lbs.) for lithium.

For solar cells, there were no restrictions for the Open Class. This allowed the team from Messiah College, for example, to accept a sponsorship from PV manufacturer Emcore in the form of nearly 3,000 space-grade solar cells. Principia College was able to accept a 90 percent sponsored donation of 2,200 gallium arsenide cells, ranging from 18 percent to 21 percent in efficiency, which is much higher than the silicon cells in the Stock Class.

Los Altos High School / La Puente Valley ROP rips through a checkpoint.

These were the teams with bigger budgets, due primarily to major corporate sponsorship. In addition to reliability and teamwork, how well they finished would be determined in part by the funds and resources available, but also by the quality of their engineering.

In both classes, the solar array had to meet specific dimensions. The solar array included not just the photovoltaic cells, but also anything that enhanced their conversion of energy, such as reflectors, refractive lenses, or cooling components. Even a wind sail would be considered part of the array, since wind is considered a form of solar radiation. (That idea has been attempted in the past, but not with any great success.)

While the car is in motion, the array had to be fixed in place at the same orientation that it had during scrutineering. (“Scrutineering” is a term adopted from gas car racing. It is the prerace inspection to certify that the car meets all the official requirements for participating.) This is just a sample of the rigid rules with which the cars had to comply. Many of these rules are the result of clever maneuvers that teams used to slip through loopholes of rules in earlier races.

The Teams

This is another place where the American Solar Challenge differs from its predecessor. While the Sunrayce was only open to university teams, the ASC was open to anyone who could field a car that met the rules. The race was still dominated by college and university teams, but there was also an independent entry, and even one high school team.

Most of the teams were American, but there were several from Canada, one from Italy, and one from the United Kingdom. Teams ranged in size from five members to thirty or more.

According to George Douglas from NREL, a common evolution occurs among solar racing teams, even though the students involved change from year to year. “The first year,” he said, “the cars are kind of crude. The second year, they’re more refined. The third year, for many teams, is a breakthrough year.”

Most of the teams in the race had some previous racing history, even though none had done a race of this length before. Some, such as MIT, have been involved in solar racing (sometimes called “raycing”) for more than a decade. For others, like North Dakota State University, this was their first time out.

The smallest team, with five members, was the private entry from Associazione Futura in Italy. Solar racing veterans since the 1996 World Solar Challenge, they put on a strong showing in the middle of the pack, besting much larger university teams.

The youngest team, in terms of members’ ages, was the Los Altos High School/La Puente Valley ROP team from Hacienda Heights, California. Although they too were solar racing veterans since the 1995 Winston Solar Challenge, they ran into some problems in this race that would set them back a few places behind the Italian team. Still, they were able to finish the race, a tremendous achievement in itself.

Kansas State University was an example of a team that wanted to really make their own mark on their car’s engineering. They developed their own process for encapsulating the monocrystalline PV cells in the array, designed the peak power tracker circuit boards, and designed and built their own lithium ion battery pack. (The peak power trackers maximize the power

Claremont, California, welcomes this PV racer.

from the solar array and regulate its flow into the batteries.)

The University of Missouri at Columbia had great success with a similar bit of engineering in the 1999 Sunrayce. They developed their own encapsulating technique, which reduced reflection and allowed their array to put out more power than any other team's array, under the same lighting conditions. These are examples of the kind of engineering creativity the event was intended to foster.

The Race

The cars set off on a sunny Sunday morning from the Museum of Science and Industry in Chicago, a fitting launchpad for the event. The starting lineup had been determined by the previous qualifying races. In those events, the winning team from Rose-Hulman Institute of Technology had the car that completed the most laps in the time allowed, with a whopping 495.60 miles (797.56 km). The second place car, from Principia College, only completed 257.56 miles (414.49 km) in the qualifier.

For the actual race, the thirty cars took off at one-minute intervals. There were twenty-one cars running in the Open Class, and nine in the Stock Class. Even with their technology limited by the rules of the class, however, the Stock entries were well distributed throughout the lineup, not gathered in a bunch at the end. The first Stock car to launch was from Stanford University, third in the overall starting lineup.

As in any type of racing, there are numerous wild cards, and the starting lineup rarely resembles the finishing order. Mechanical problems (such as flat tires), and even ordinary city traffic caused routine delays. At one point, an accident on the race route forced a detour on rough roads.

Weather was one of the big concerns. On the second day out, cloudy skies brought some of the cars down to minimum speed to conserve energy. And the teams had to deal with clouds and rain several times throughout the race. At other times, temperatures of 100°F (38°C) or more made cooling a critical issue, for both components and drivers.

Checkpoints doubled as pit stops, and well-rehearsed teams like the crew from Principia College rolled smoothly into action. Each member had an assigned duty, and they flowed around the car in a complex dance, checking a myriad of items on the car within minutes. Then, when their required stop time had elapsed and the officials had cleared the car, it was back on the road again.

The veteran team from the University of Missouri at Rolla quickly took the lead. Attrition began early. By the end of the second day, only thirteen of the thirty starting teams had reached the checkpoint solely under their own power. The other seventeen had trailered in.

Throughout the race, many teams were forced to trailer portions of the route and accept the penalties for doing so. This could be due to weather problems, breakdowns, or simply dropping too far behind. It was sometimes considered a practical strategic move to take the penalty for trailering in order to stay in the race. Then, once the team got ahead of the bad weather or made changes and repairs to the car at the next checkpoint, they hoped to make up for the penalty time.

The will to finish was strong in the teams, and no one wanted to give up. The overall mood was "California or bust." McMaster University and the University of Pennsylvania experienced problems with their cars that forced them to drop from the race because they could not maintain the minimum average speed of 25 mph (40 kph).

The first-time team from the University of North Dakota and veteran racers from Principia College both experienced battery problems that forced them to replace cells and take a penalty, as did the University of Toronto later in the race. A suspension part broke on the Iowa State University PrISUm car while crossing a rough portion of the old highway. But the well-prepared team quickly swapped in a replacement and got back on the road, while fabricating some more heavy duty components to swap in at the next opportunity. These were just typical challenges of solar racing.

The Open Class cars, with their more effective (and expensive) solar arrays and batteries, quickly took over the top several positions in the race, as could be expected. The competition developed into a closely fought battle between the University of Michigan and

the University of Missouri at Rolla. The University of Waterloo and Queen's University also made excellent showings, and each finished in first place for some segments of the race.

In Oklahoma, Rolla was forced to push their car across a particularly rough railroad crossing. When the car got stuck on the tracks with a train bearing down, they hurriedly pushed it off backwards. They then discovered that a soft tire had allowed some damage to the wheel cover, so they were delayed while they made repairs.

One hallmark of solar racing, since its inception, has been the spirit of courtesy and cooperation among the teams. On the third day of the race, Iowa State University began to have problems with their peak power trackers, and could not get enough charge to make it to the next checkpoint. MIT, learning of their problem, donated some trackers to the effort, and got their competitor back on the road.

Similarly, in Arizona, the University of North Dakota was taken out of the race by damage from a cattle crossing grate. However, they not only called to warn competitors and flagged them past the bad spot, they also offered any equipment needed to their bitter rival, North Dakota State.

The Finish Line

Although Rolla came back strong after their difficulties, they could never quite catch Michigan again, and came in second to Michigan by an hour and twenty minutes. This was still a remarkably close finish for a ten-day, 2,247 mile (3,616 km) race.

The University of Arizona was the first place finisher in the Stock Class, completing the race in ninth place overall, well ahead of many Open Class cars—an impressive achievement.

All in all, the race was a very successful event. According to Gary Schmitz, support from the communities along the race route was strong, and very warm. "It was great," he added, "to see these futuristic cars juxtaposed with icons of the past."

Spirits were high for participants throughout the field. As was apparent in the daily e-mail newsletters issued by the Iowa State team, the act of building the car and running the race was itself a victory, regardless of finish position. The teams measured their success more by how much they had achieved than by comparing themselves with other teams. Once again, the journey was more important than the destination.

Many things happened in ten days besides the running of a car race. People across the country got an up close look at renewable energy technology in action. Maybe some of them started to think of solar energy as something "real." Some of tomorrow's engineers got a chance to test their design and problem-solving skills on a real world project.

And, in the best traditions of the Mother Road, another generation climbed into their shiny machines, answered the call of the open road, and made their own memories on Route 66.

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Gauges for Electric Vehicles

Mike Brown

"What kind of gauges do I need in my electric vehicle?"

Electric vehicles (EVs) can have a variety of gauges, just as fuel-powered vehicles do. We need to know how much electrical energy our EVs have available for the same reason we need to know how much fuel we have in our car or truck. We need to know other information about our EV as we drive. Most of it is different from the kind of information supplied by the factory gauges and warning lights that originally monitored the gas or diesel engine before conversion. Let's take a look at the world of EV gauges.

Pack Voltage Gauges

Let's start with the fuel gauge. You may be accustomed to measuring the state of charge on an RE system battery pack. You probably use an amp-hour meter to do this, because a plain voltmeter isn't accurate enough. This makes sense on a battery bank in an RE system, where the constantly shifting input and output can cause huge variations in the voltage reading for a pack at the same state of "fullness."

The situation is different in an EV. For one thing, you are never trying to check the pack's state of charge on the dashboard gauge while it is charging. Unless you have regenerative braking (and most home conversions do not), the only time the car is charging is when it is parked in the garage. In that situation, you monitor the gauges on the charger, not on the dash.

The car is also not charging and under load simultaneously. If you are driving down the road, the only variable affecting your voltage is load. Lift your foot from the throttle pedal, and you have a neutral situation—no charging, no load.

The easiest way to measure an EV battery pack's state of charge (SOC) is with a voltmeter that reads from 0 to a voltage level about 10 percent greater than your nominal pack voltage. For example, a fully charged 96 V nominal system will actually read about 106 V. The extra 10 percent is called "surface charge." It disappears quickly (in the first mile or so) once you start driving, so it shouldn't really be included in your usable charge calculations.

After you have had a little experience driving your EV, you will know what voltages represent full and empty. You may even want to put tape marks on the face of the gauge for quick reference.

Readability is a problem for simple voltage gauges because getting all the information necessary on the face of a 2 inch (5 cm) gauge makes for very small numbers and tiny marks. An expanded-scale voltmeter can help. For most EVs, these read from 50 volts on the bottom of the scale to whatever is the highest reading on the scale. You don't need to measure below 50 volts because the controller's low voltage cut-out feature will shut the controller off when the battery pack voltage reaches 48 volts.

This narrower range of measurement means fewer numbers and marks in the same space, which allows them to be bigger and more readable. Put tape marks at the full and empty points on the gauge scale. Then you can use the relationship between the tape marks and the needle to determine your state of charge at a glance, and you'll have a usable fuel gauge.

State of Charge Gauges

Since you are not reading the exact voltage at that time and then mentally calculating your state of charge, you have to ask, "Do I really need to have a gauge that reads in volts?" This question leads us to the state of charge, or SOC gauge, the simplest and easiest to use "electric fuel" gauge.

This is also an expanded scale voltmeter, but it reads a different range of voltage, and the face is labeled differently. An EV battery pack is considered "drained" at 80 percent of full voltage, so only the top 20 percent of the voltage range is actually usable. The SOC gauge measures only this usable portion of the batteries' charge, and for this reason must be ordered to suit an exact battery pack voltage.

The face of the SOC gauge is labeled in percentages from 0 to 100 percent instead of in volts, with 0 actually being the 80 percent level discussed earlier, which is the battery equivalent of empty. The SOC gauge gives you the information you need to know in a simple, readable form.

Since voltmeters, whether SOC gauges or not, are tied to the battery pack and show the real time voltage of the pack, the voltage shown will fluctuate as you drive. This is due to the voltage sag caused by the current draw of the motor under varying amounts of load. For this reason, a voltmeter only gives an accurate reading of the battery pack's charge level when the power is off while coasting or sitting still. However, in an EV, you tend to coast often, because EVs coast much faster and longer than gas cars.

Another type of SOC gauge is the sampling voltmeter. This solves the problem of fluctuating readings, but introduces another problem. About ten years ago, we tried out a sampling SOC gauge that was an adaptation of a golf cart unit. It measured the battery pack voltage every few seconds. Instead of numbers, it displayed a column of eight LED bars, and shut off one LED segment every time the pack voltage fell below a predetermined point.

This system worked fine on golf carts, which draw low amps and have little battery sag. When we put one in our Voltsrabbit to test it, we were surprised to find that the LED bar read half full while the voltmeter in the car showed the pack to be still full. What happened was that we took a high speed, high current run up a hill by the shop. The SOC gauge had sampled the pack voltage at a point when it was being pulled down by a sustained 400 amp draw, and the gauge set the LEDs accordingly. Since this unit wouldn't reset to full until the pack was fully recharged, it stayed at half full. Needless to say, that was the end of the test.

Current Flow, or Efficiency Gauge

An ammeter measures the power that the drive system is pulling out of the battery pack at a particular point in time. This real-time consumption gauge has no equivalent in the gas or diesel vehicle world.

By watching the ammeter as you drive, you will notice what your amp draws are during different parts of your trip. After you have established a baseline for your trip or parts of it, you can start honing your driving techniques to use less energy for the same trip. Think of it as a new game: Beat the Ammeter.

Another use for the ammeter, and the baseline draws you have established, is as a failure warning system. If, during your daily drive, you notice that you are pulling more amps than usual consistently throughout the trip, it might be an indication of a problem with the EV. An increase in amp draw often means an increase in rolling resistance, which could be caused by a tire going soft from a slow leak, dragging brakes, or a wheel bearing going bad. The ammeter will warn you of such things long before anything else will.

The ammeter and battery pack voltmeter (or state of charge meter) are the two gauges necessary in an EV. The next two gauges are nice to have, and may already be in the car or truck you are converting, so why not use them?

Accessory Battery Gauge

In addition to the high voltage battery pack that drives the motor, an EV has a normal 12 volt battery to power accessories. The low voltage voltmeter, or auxiliary battery voltmeter, used to be an essential gauge to have when the auxiliary battery was a large, 12 volt deep-discharge battery that was only charged along with the traction battery pack at night.

This "total loss" low voltage system had you watching both the battery pack voltmeter and the auxiliary battery voltmeter with the same amount of fascination and dread. Which was going to give out first? A car that had miles left in the main pack could still be stranded if the auxiliary battery, which supplied power to some of the control circuits, ran out of juice.

Now DC-to-DC converters are commercially available. These constantly charge the auxiliary battery from the traction battery pack. So the 12 VDC auxiliary battery meter is a nice accessory instead of a must-have component. Use it to keep an eye on the DC-to-DC converter operation, and to monitor the amount of draw your "killer" sound system is putting on the auxiliary battery. If the car or truck you are converting has a voltmeter as part of its instrument panel, you have one less part to buy.

Tachometers

The tachometer is the other "nice but not necessary" gauge. The tach, as it is commonly called, is handy to pinpoint proper shift points based on the revolutions per minute (RPM) rating of your motor. It can also help you maintain the right motor speed in each gear for maximum efficiency. However, if you calculate the peak mph for each gear based on the motor's peak rated RPM, and mark the speedometer with bits of tape at those speeds, you have a shift point indicator that is simpler and easier to use than the tach.

As far as the tach being an aid to efficient operation, the ammeter described above is a much better gauge to use. Even if the tach came with your donor vehicle, you will have to add a tach driver to the EV to make it work. We'll talk about that in the next issue.

Amp-Hour Meter

One other gauge is out there—the amp-hour meter. This meter is used by the more technically inclined EVers. It is programmed with the amp-hour capacity of the battery pack and several other variables. Then,

while the EV is being driven, it calculates state of charge, amp-hour capacity remaining, or operating time remaining at the present rate of discharge.

I looked into this unit several years ago, and decided not to use it. My decision was based on the cost of the gauge, the amount of programming necessary, and the number of variables that affect the accuracy of the information it provides. My philosophy of electric vehicles has always been to keep them as simple and easy to operate as possible. This meter added a layer of complexity and expense that I didn't want or need for a daily driver. Some racers and hobbyists who want lots of very precise data really like them.

Original Factory Gauges

Now that we know which gauges are necessary and which are optional, we should look at the types of gauges available. The first gauges to look at are the ones that came with the donor vehicle. The instrumentation in an economy car can be a speedometer and a cluster of lights or lighted icons that indicate either normal operation or a problem. The reuse of warning lights or icons will be discussed in the next issue.

The more upscale cars and trucks come with a speedometer and tachometer, and the full array of voltmeter, oil pressure, and coolant temperature gauges. As mentioned above, the voltmeter, tachometer, and speedometer/odometer are the only original gauges that can be directly reused in an EV. Converting the fuel gauge to a state of charge gauge has been done, but it's difficult to do and may not be reliable. Other original gauges either have nothing to measure in an EV, or would be more trouble than they are worth to adapt.

Panel Meters

The shortage of EV-compatible gauges on donor vehicles means that we have to install gauges that give us the information we need. Let's take a look at what is available. The early EV builders used a combination of surplus gauges and panel meters. It was often hard to find a gauge with the proper calibration, and with a face that read within the range needed.

One of the early EV kit suppliers, Ric Barline of Siskiyou Energy Systems (SES), solved this problem by designing his own gauge faces and calibration systems for a readily available Radio Shack panel meter. The SES gauges gave a nice uniform look to the dashboard of a conversion, and presented the needed information in an accurate and readable manner.

There were still problems. The biggest problem was that there was no provision for lighting the gauges for night driving. Some builders provided external lighting, but it was a tricky task to illuminate the gauges without lighting up the whole driver's compartment.

Some of the other problems were related to environment. Since a panel meter is designed to be used in a protected environment, the movements are not sealed against dust and moisture. In a vehicle, the meter is exposed to both of these, and failures occur. The custom faces were printed on heavy paper, which warped when it came into contact with moist air. It also lifted away from the gauge and blocked the needle's movement. If the gauge was exposed to full sunlight on a regular basis, the printing on the face would start to fade.

Other problems were mechanical. The on-road life has two other conditions that the panel meters couldn't take—vibration and shock. Once, when I was driving an early EV, I hit a bad pothole in the road and the needle on the ammeter fell off. Custom-faced and calibrated panel meters were a good step forward, but they were not the final answer.

Automotive Spec EV Gauges

Since I was selling these SES gauges and replacing quite a few under warranty, I began looking for a better way. I remembered a small local automotive gauge manufacturer that I had bought some gauges from for a Formula Vee race car I was working on. I re-established contact with them, explained my problem, and asked if they could help.

Their response was yes, they could supply a 2 inch (5 cm) diameter, sealed automotive style gauge. It would have a provision for lighting, and would be calibrated and faced to suit my requirements. Oh, and by the way, did I want my company logo on the face?

In ten years of selling these gauges, we have had one failure that wasn't due to the gauge being hooked up improperly. The factory repaired it at no charge. Having a gauge that was designed for an automotive environment, and a helpful manufacturer willing to customize the face at the factory, made all the difference in the world.

Digital vs. Analog

Since an EV is a new high-tech vehicle, shouldn't it have high-tech digital gauges? An instrument panel full of flashing LED or blinking LCD numbers is certainly more impressive than a row of automotive style analog gauges. Digital has to be better, right?

In a word, no. At issue is the usefulness of the information. When you are driving your gas car and you look at the gas gauge, you see that the needle is about a quarter of the way down from the full mark, and that's all you need to know. A digital meter would have told

you that there was 7.5 gallons in the tank. This leaves you to figure out, “OK, it’s a 10 gallon tank, so 7.5 gallons is 3/4 of 10 gallons, and I must have 3/4 of a tank left.”

This is another difference between an RE system pack and an EV pack. In an EV, you want to be able to check your fuel at a quick glance, without any excess mental processing required. On an RE system pack, you can give it your full attention, because you aren’t trying to simultaneously steer it down the road at 60 mph.

The example above illustrates the difference between a gauge and an instrument. A gauge gives you a quick, accurate indication of an amount or condition, and may not display any numbers at all. Instead, it graphically displays a position between a top point and a bottom point. An instrument gives you an exact number, which you must compare with other numbers in your head to turn it into useful information. While an instrument is more precise, a gauge is more intuitive and easy to use at a glance.

Due to the fact that I use my EV for testing as well as transportation, I have a test port I can plug a digital voltmeter into during test drives. However, when I am making a grocery run, I use the SOC gauge. Anything else would be, like the woman in the film *Pulp Fiction* said, “just a little more information than I need right now.”

On the other hand, some LED gauges, like the sampling voltmeter I talked about earlier, just display a few bars of light instead of numbers. These really don’t give you enough information. Visibility in bright light is a problem for both LEDs and LCDs, and unless they are backlit, LCD gauges have a problem being seen in the dark.

Necessities & Options

What it all boils down to is that there are two essential gauges: the high voltage battery pack voltmeter or state of charge gauge, and the high current ammeter. Any other gauges are up to you, and depend on what information you want to know.

We have just taken a tour of the world of EV gauges. We now have an idea of what we need, what we might like to have, and what we might be better off not having. In the my next column, I’ll look into the ways to mount and wire gauges for electric vehicles.

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Renewable Energy Terms

Direct Current (DC)—Uni-Directional Flow of Electrons

Ian Woofenden

Derivation: From Latin directus, *straight, direct, level, and Latin* currere, *to run.*

Two common forms of electricity are direct current (DC) and alternating current (AC). In most American homes, AC is the standard. But examples of DC electricity are quite common.

Batteries are DC devices. So any system that includes batteries is using DC. This includes the starting, ignition, and lighting systems in your car, boat, or RV. It also includes any device that uses small batteries, such as a flashlight or radio.

Electrical current is the flow of charges. In a metal conductor, those charges are electrons. Instead of thinking of “current” as something that moves through wires, remember that it’s actually the *rate* of electron flow. Just as “current” in a river describes the movement of water, electrical current describes the movement of electrons.

People often talk about electrical current as if it’s “stuff.” But it’s describing an action, not a thing. We don’t say that “the current moved down the river” and think that there’s “stuff” called “current.” We know that it’s water that moves. In electricity, it’s electrons that move.

An ampere or amp is the unit of measurement for this electron flow. One amp is one coulomb per second. A coulomb is 6.28 billion billion electrons. The movement of these electrons through a conductor is what we call electric current, and it’s what makes our appliances and lights work.

The key thing to remember about direct current is that the electrons flow in only one direction. The flow is from the negative terminal of the battery through the circuit wiring, to the positive terminal, through the battery, and back around.

In the early days of American electrification, the proponents of using DC debated with the proponents of AC. Edison was promoting DC as the best standard, while Westinghouse and Tesla were pushing AC. The AC camp won. The primary advantage of AC over DC is that it’s easy to transform it to and from high voltage. This allows easy transmission over long distances. (Some long distance transmission lines do now use high voltage DC.)

So why has DC survived at all, and why do we use it in the renewable energy industry? Well, photovoltaic panels are DC devices. Wind generators and hydroelectric turbines can be designed to produce AC, but PVs cannot.

If we have PVs in our systems, we’re dealing with DC. This means that we (or our electricians) need to educate ourselves about the characteristics of DC, and the proper equipment to use it safely. Most DC in RE systems is low voltage, which brings another group of challenges that are different from standard AC wiring.

Batteries are also DC devices. So as soon as we want to store electrical energy in our renewable energy systems, we’re dealing with DC. We are often faced with not only low voltage, but with high current from the battery bank to the inverter. An inverter converts DC into AC, for use by standard appliances. Some DC devices, like DC compact fluorescent lamps, have small inverters inside to supply AC internally.

Compared to alternating current, direct current is pretty simple and predictable. Ohm’s law (volts = amps x ohms) can be applied consistently, and the basic principles of DC electricity are fairly easy to grasp. Imagining electrons flowing in one direction through source (battery, PV, or generator), wiring, switch, and load gives you a pretty good picture of direct current.

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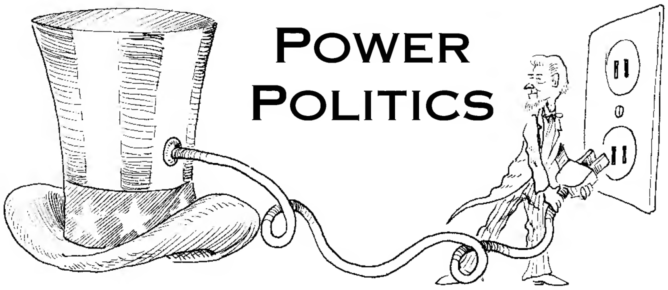

Energy Shortage, Vision Shortage

Michael Welch

A new administration means a new energy plan. Vice President Cheney has gotten together with his corporate friends to decide what energy policy is best for us (well actually, for the corporations). In related news, President Bush has opted out of the Kyoto Protocol discussions. Unfortunately, since he represents us, the United States is out as well.

OK, I may be a bit cynical these days, but there are some bright spots for the future. For example, if we can figure out how to keep energy prices from going down, we may just be able to convince people to make conservation a permanent part of their lives. And renewable sources of energy might just get the kick they need to really take off. Of course, along with that, we need to figure out how to make electricity available to the poor at a reasonable cost.

Congressional Hearings Possible
Cheney and his energy task force met in closed sessions with oil, gas, and other corporate representatives to come up with the Bush administration's proposed energy policy. Needless to say, neither you nor I were invited. The (not unexpected) result of those meetings is a policy that calls for more oil and gas exploration, more fossil fuel-powered electrical plants, more nuclear power, and less attention to conservation, efficiency, global warming, and renewable energy.

Not only did this upset folks in the environmental movement, but it has also given fodder to the Democrats, who like to pretend publicly that they are above such backroom corporate dealings. Since Senator James Jeffords of Vermont abandoned the Republican Party, giving Democrats control of the Senate, Democrats have taken every opportunity to foil the recently installed administration. They have even considered Congressional investigation into Cheney's back-room dealings.

The General Accounting Office has requested any listings of nongovernment people who attended Cheney's energy task force meetings. The Vice President has refused as a matter of principle to provide those lists, saying that there was no one the panel met with that "would be at all surprising."

Cheney calls on "principle," but any principle is suspect that can be turned around to justify the destruction of Alaskan Wilderness to help his oil and gas friends make money.

This issue seems headed for the courts. At the same time, private organizations are trying to obtain those lists through the Freedom of Information Act.

"Drill America First" Energy Policy
Keep in mind that the Bush energy policy is not law. But it is the starting point for any decisions that come out of the administration. And it dovetails with the administration's budget recommendations, which are usually the source for Congressional spending discussions. At magazine deadline, the House of Representatives had just approved the budget for the Bush energy policy. It will likely not pass in the Senate as is, so a conference will be called to hash out the differences.

According to the Save Our Environment Action Center, a collaborative effort of several influential environmental advocacy organizations, "In theory a national energy strategy is a good thing—*if* such an effort begins to move America towards a cleaner, more reliable energy future. The President's budget recommendations slashed funding for energy efficiency and conservation while offering US$2 billion in new funding for coal plants. His energy plan continues on an unbalanced path that threatens public health, the environment, and our public lands."

Implementing the Bush energy policy would:

- Open the Arctic National Wildlife Refuge and other public lands to drilling.
- Increase air pollution by weakening the Clean Air Act and other pollution requirements.
- Increase subsidies to coal and nuclear industries.
- Fast-track the relicensing of nuclear power plants.

- Renew the Price-Anderson Act, which limits nuclear power plant liability.
- Increase global warming pollution.
- Encourage construction of new nuclear power plants.
- Override local land use decision-making.

Obviously, the Bush/Cheney plan is focused on increasing energy supply, and doing it in such a way as to benefit administration cronies rather than improving energy efficiency or helping consumers. Bush cleared up his position on the need for power plant construction with his statement, “The California crunch really is the result of not enough power-generating plants and then not enough power to power the power of generating plants.”

Even though the proposed Department of Energy (DOE) budget focuses on new sources, it would decrease funding for renewable energy R&D by 50 percent, while DOE overall cuts were only about 4 percent. That means that coal, oil, gas, and nuclear energy are all getting substantially increased attention at the expense of cleaner technologies.

Climate Change News

In July, the historic Bonn climate change agreement was reached, finalizing the Kyoto Protocol for greenhouse gas reductions worldwide. Each country still needs to go home and get the treaty ratified by its official government.

Though many argue that the agreement is too lightweight, at least something was finally agreed to by the 178 countries involved. Everybody was there, except the United States. President Bush decided not to support the protocol, claiming that the policies would hurt U.S. businesses too much. Since the burning of fossil fuels is the number one culprit contributing to global warming, I’ll give you one guess as to which businesses he was protecting.

One piece of news out of Bonn surprised a lot of folks. The countries in attendance all agreed to leave nuclear power plants out of the “clean development mechanism.” This mechanism allows industrialized countries to claim carbon credits for emission-cutting investments in developing countries.

Since then, the nuclear industry has come unglued, stepping up their campaigns on all levels, including domestic U.S. efforts. All the millions of dollars they spent in recent years trying to convince the public that nuclear power was necessary to prevent global warming did not work.

Shaun Burnie, a campaigner for Greenpeace International, said of the decision to leave nuclear power plants out of the clean development mechanism, “This is very bad news for the global nuclear industry, in particular in the implications for the Chinese nuclear reactor construction program, where they were hoping for credits to offset construction costs.”

Tell Them You Want Renewables

The best action we in the U.S. can take right now is continue to pressure our House and Senate representatives to even the playing field between the renewable and nonrenewable sources of energy. They are on the verge of buying into the short-term solution of building more conventional power plants and finding more fossil fuels. Let them know that’s not OK with you.

Ask them to support solar, wind, conservation, and energy efficiency. Ask them to stop supporting fossil fuels and nuclear power. Call your Senators and Representative at 202-224-3121 to tell them what you think.

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Don Loweburg

Latest on California Buydown

With the combination of an increased rebate (up to US$4.50 per watt) and continued utility uncertainties, the California rebate program enrollment has increased dramatically. From December 1998 to December 2000 (24 months), the number of applications per month averaged fewer than 50. In January, reservations exceeded 150, and have gone up steadily. For June, the number of reservations may exceed 400.

When all current reservations are installed, the total PV capacity under this program will exceed 8 megawatts by the end of the year. There is little doubt that the momentum for this program is still building, and we can expect this to be the most successful PV program in the country. The success of this program should make it clear to all policy designers that giving incentives for the end user to install PV is the best program model to promote.

The California rebate program is well run, and the staff at the California Energy Commission (CEC) should be congratulated. The CEC has improved the Web site supporting this program, and will soon include online registration and updated status reports.

Utility-Run PV Programs—A Bad Idea

Recent legislation, ABX29, directed the California Public Utilities Commission (CPUC) to administer US$125 million per year for a self-generation program. A large portion of this funding could go to PV systems in the 30 KW to 1 MW size range. This support is directed more at the commercial sector than the residential. This added support for renewables is very welcome, but one element of the program must be criticized.

It is unclear exactly what dynamic was at play, but this program was turned over to the utilities to administer, except in the San Diego region. Why would anyone turn over the administration of any program to the bumbling bankrupt utilities of California? Pacific Gas & Electric's (PG&E) molasses-slow administration of their own net metering application process should be enough evidence to dissuade placing any program administration in their hands.

San Diego Gas and Electric declined to administer the program, creating an opportunity for third-party administration. In San Diego, the program will be administered by the San Diego Regional Energy Office (SDREO), an independent, public-benefit, nonprofit corporation. I believe this is a very good move, and I expect SDREO to do a better job administering this program than the utilities.

I hope this approach can be replicated, not just in other parts of California, but throughout the rest of the country. Policymakers must get it straight. Utilities are no friends of renewables or independent generation. Successful programs must be administered by renewable-friendly, third-party agencies.

Net Metering in Hawaii

Hawaii joins 33 other states and now has net metering. With two additional states pending, the national total may soon be 36 states. As is the case in many states, the Hawaii program has serious limitations. Some of these are a 0.5 percent cap on total capacity, a 10 KW cap on PV system size, and no monthly forwarding of excess generation. On the plus side, the program includes PV, wind, hydro, and biomass. Any reader is welcome to contact IPP for a copy of the net metering states, which has been compiled by Tom Starrs. Or check the *Home Power* Web site.

Predicting System Performance

Last issue, we reviewed Sandia Lab's latest research on evaluating module output. To summarize, the STC (nameplate) rating of modules can be a good standard for module comparisons. Modules with the same STC rating will produce nearly equal annual energy output in

similar locations. When evaluating modules, using the annual energy output makes the most sense.

Predicting system performance is more difficult, but it makes sense to use energy output as the most meaningful measure. However, predicting system output requires characterizing the interplay of the various components (inverters, modules, controllers, system wiring, combiner boxes, etc.). The industry has been slow to deal with this aspect. One reason, I believe, is that the results are somewhat disappointing when compared to the overly simplified output estimation methods of the past.

In days past, when someone asked how much energy a system produced, it was common practice to take the insolation value (those numbers on the sun charts with the wiggly lines) for a given location and multiply that number by the STC array output. The result of that calculation was then presented as the predicted daily energy output of the system. There is only one problem—the answer is optimistic to the point of being seriously misleading.

As stated before, it is the interaction of a series of component and site factors taken together that determines system output. As an example of how this works, consider a simplified, batteryless grid-tied system of modules, inverter, and balance of system components (wiring, breakers, etc.).

If each element in the system functions at 90 percent of its rated capacity (not a bad assumption), the combined system efficiency would be the product of the individual efficiencies (0.9 x 0.9 x 0.9) or about 73 percent. Using the naive and optimistic estimating method for a 1 KW (STC rating) array in a five-hour sun zone, we would predict about 5 KWH per day. Using the more realistic method, we would predict about 3.6 KWH per day. The second answer is closer to the real world results.

This example is for a system without batteries. If a battery is used, a system's energy yield may only be 50 percent of the insolation potential! As more systems are installed, it is clear that designer-installers must be more accountable for system energy yield. Those interested in a system design course for installers should contact Bill Brooks at Endecon Engineering.

Inverter Warranties

One of the espoused goals of the California Energy Commission (CEC) rebate program was to raise the bar of technical excellence for PV systems. Besides spot checking the quality of installations and requiring that systems be permitted, the CEC's main method for achieving system quality was to insist on a five-year, full system warranty.

Full system warranty means labor and materials. The full warranty is required for dealer installs. From the outset, IPP supported the goal, but advocated that the manufacturers should provide a suitable five-year warranty. What many may not know is that installing dealers have been required to purchase an extended inverter warranty from some manufacturers, such as Xantrex.

Last July, I thought Xantrex had finally seen the light. In a July 6, 2000 news release, I read, "Trace Engineering's Sun Tie inverter certified for California solar program... Sun Tie inverters have a standard two-year warranty; systems registered as part of the CEC Buydown Program have a five-year warranty." It did not say anything about purchasing an extended warranty. I think the words are pretty clear!

Xantrex has disavowed the existence of a standard five-year warranty for California rebate systems. On the occasions that I have referred Xantrex staff to this press release, they have said they will get back to me. To date, I've had no response. I would be happy to offer column space so that Xantrex can clear up this issue. Put simply—disavow the press release publicly or honor it.

There is some very good news relating to the warranty issue. Advanced Energy Systems offers a standard five-year warranty on their GC-1000 and MM series inverters. Last column, I mentioned that a German company, SMA, was introducing its grid-tied inverter, the Sunny Boy 2500. Recently, John Berdner, president of SMA America, while introducing his product at a PV Alliance meeting (June 27, 2001, in San Francisco) finished his presentation with the statement that Sunny Boy would carry a five-year warranty when installed in a California rebate system. John's willingness to raise the bar was greeted with resounding applause from the Alliance members. We also applaud the other manufacturers willing to follow suit.

Time of Use (TOU) Net Metering

How does TOU change PV economics? What is the value of TOU net metering? To get an idea, consider a hypothetical home that uses 20 KWH per day, or 7,300 KWH per year. At US$0.15 per KWH, the annual electric bill would be US$1,095.

Now let's install a 2 KW PV system on that home and keep the same rate structure. The PV system will produce about 8.5 KWH per day, or 3,102 KWH per year. Valued at US$0.15 per KWH, the power produced by PV is worth US$465 per year.

We are assuming that the home is in California, and that the PV system receives a 50 percent rebate,

lowering the installed cost of the system to about US$10,000. Dividing this by the value of the PV power produced (US$10,000 ÷ US$465), we get a simple payback of 21 years. The customer's annual electric bill under this scenario is US$630.

TOU net metering may not be a good choice for all households. It is very important to understand that you must have net excess generation during the peak period (usually noon to 6 PM weekdays) to benefit. If this is not the case, a person might do worse with TOU net metering. The assumption for this analysis is that the example household can control daytime peak loads so that 3 KWH per day can be sold back to the grid during the peak rate period.

With TOU off-peak pricing of US$0.085 per KWH, the 7,300 KWH consumed annually now costs US$620. This is offset by the off-peak value of the PV self generation, which is US$264 (3,102 KWH x US$0.085 per KWH).

Next, we account for the on-peak value of the PV sold to the grid. The on-peak rate usually applies for weekdays, and is limited to six months of the year. This amounts to 130 days per year. Assuming that the house sells 3 KWH per day, the yearly on-peak energy sold is 390 KWH (130 x 3). These KWH are worth US$84 (390 x US$0.215). The PV savings is US$348 (US$264 + US$84). The customer's yearly electric bill is now US$272 (US$620 - US$348).

Compared to the initial non-PV scenario, the customer saves US$823 per year (US$1,095 - US$272). The simple payback is now twelve years (US$10,000 ÷ US$823). This analysis is necessarily fuzzy, and utility rates differ from region to region. But it should be apparent that in the right situation, TOU net metering significantly improves the economics of installing PV.

Presently California is the only state with TOU net metering, though 34 states have some form of net metering. In addition to expanding net metering to all states, it should be the industry's goal to extend TOU to all states and eliminate the crippling constraints imposed by most utilities.

These constraints on system size and overall enrollment, the utilities argue, are necessary for technical and management reasons. This position is totally bogus. If unscheduled generation (PV and other distributed generation like wind) were to reach levels of 20 percent of grid capacity, this position might make sense. The fact is that utilities are attempting to stifle independent generation, and are obfuscating their intentions with spurious technical issues.

Are PV Kits a Good Deal?

In *IPP, HP83,* I discussed the Siemens Earthsafe kits, and the fact that most manufacturers were offering kits. Recently Kyocera introduced its line of kits. As stated before, I am no fan of kits. I perceive kits as an attempt by marketers to dumb down the industry. It is galling to me to see generic, off-the-shelf components boxed up and branded. This kind of marketing shows little imagination, and does not create any value to the end user.

Who or what do these kits support? Is it the customer? I don't think so. Usually the customer will pay more by the time the system is installed. Do installers benefit? Not the competent ones; they can design systems! The only installers who might benefit are ones who cannot or will not design systems. The primary beneficiary of kits is the manufacturer. By bundling balance of system components into a package, these companies can make a small additional profit (taken out of the dealer's shrunken margin).

Manufacturers also benefit by expanding their marketing base beyond the competent dealers in the existing distribution chain. Expanding the distribution network to include unqualified installers does not serve the industry or the customer. A final concern is that there is currently a shortage of modules and inverters. Does this mean that dealer-installers are now competing with manufacturers for balance of system components (like inverters!)? How many inverters get tied up in kit inventory and are unavailable to fulfill orders by installers who design customers' systems?

More on Fuel Cells

In *IPP, HP84,* I referred to fuel cells as a red herring. Ian Woofenden, my editor, made some great suggestions, which I didn't elaborate on at that time, but I do want to now. Though the article focused primarily on fuel cells using carbonaceous fuels, Ian challenged the premise that pure hydrogen fuel cells would have a major role in a renewable future. Though this view strikes at the Holy Grail of renewable theology, he makes a good argument.

Ian's focus was on the source of hydrogen. Though it is the most abundant element in the universe, it does not exist in free form. To get hydrogen, energy must be expended. Most people envision electrolytic breakdown of water as a source for hydrogen. In this process, an electric current (ideally produced by renewable generation) is passed through water, breaking down the molecules into hydrogen and oxygen. This is not a very efficient process.

Another major challenge to a hydrogen economy is the storage of hydrogen. Currently, this is very expensive. When we examine the entire system—electrolysis, storage, fuel cell—the overall efficiency may be less than that of simple battery storage PV systems.

In *IPP, HP84,* I referred to hydrocarbon fuel cells as a bridging technology, and suggested that maybe they could help jump the gap from a nonrenewable to a renewable culture. Ian prodded me to elaborate a bit here. Actually, we have already jumped the gap, but I was blind to it.

Hydrocarbon fuel cells can only be considered a bridge technology if we regard the hydrogen fuel cell as the desired goal. But why do we need fuel cells in a system of grid connected PV? The grid takes the place of storage. Of course, the grid is not 100 percent reliable, and backup capability will continue to be an important option for PV systems. But if we had more PV and renewables on the grid, it would be more reliable, and the need for backup would be less. Using hydrogen (an energy storage medium) is an unnecessary and expensive step when we are dealing with grid connected PV and other renewable generation sources.

Only if energy storage were essential (as in off-grid applications) would a hydrogen fuel cell make sense. And then, only if the combined efficiency of the electrolyzer, hydrogen storage system, and fuel cell was greater than battery storage or other means like flywheel storage.

Grid Crashes on Line

The California Independent System Operator (CaISO) manages California's grid. This entity is responsible for balancing electric supply and demand for the California grid, and for managing the system. CaISO maintains a Web site where anyone can check out the current status of the grid and receive notice of any pending blackouts.

One very interesting feature on the Web site is a real time plot of actual demand, predicted demand, and supply. Of course, when the demand line crosses the supply line, someone somewhere is having a blackout. Being able to check this out in real time is very cool.

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Ogling Overcurrent Devices

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

In the *Code Corner* column in *HP84,* I looked at some general characteristics of overcurrent devices. In this column, I'll examine where overcurrent devices (fuses and circuit breakers) should be used, and how to size them. First, let's look at what short circuits are, and where overcurrent devices may not be required.

Short Circuits

We normally think of a short circuit as a very low-resistance, hard contact between two conductors. However, a short circuit can be any unwanted connection between two conductors or a conductor and a grounded surface. That connection could be a low-resistance connection, but it may also be a higher-resistance connection that will still allow damaging current to flow.

Short circuits are also called faults. A line-to-line fault occurs between two conductors of a circuit. A ground fault occurs between an ungrounded conductor and a grounded surface. Faults may result in low currents (high resistance) or high currents (low resistance).

Where Is Overcurrent Protection Not Required?

Before we look at where overcurrent protection is required, let's examine systems where it is not required. First, we must remember that we are protecting conductors from overcurrents. The circuit conductors in most power systems are sized to carry 125 percent of the continuous load currents. In the case of PV source and output circuits, this continuous current is 156 percent of the module short-circuit current.

PV modules and arrays can put out more current than the rated short-circuit current. This can happen every day around solar noon because then the sun is frequently brighter (greater insolation) than the standard value of 1,000 watts per square meter. This requires an additional 125 percent factor for PV source and output circuits. The two 125 percent factors combine to yield 156 percent (1.25 x 1.25 =1.56).

If the power sources in the system can provide power in excess of 125 percent of the continuous currents, there is probably a need for overcurrent protection. Some of these power sources might be the utility grid, batteries, large PV arrays, generators, and other energy sources or storage devices.

One type of PV system may not need any overcurrent protection. This is the direct-connected PV system, without batteries, using only a single string of series-connected modules or a single module. All of the wiring between the modules and the load is sized at 156 percent of the module short-circuit current (Isc). In this system, no battery or other source of energy can provide high overload or short-circuit currents, so the conductors are safe for these currents. No overcurrent protection is needed. A direct-connected, PV-powered water pumping system is an example of such a system.

A means of disconnect, such as a pull-out switch, is required. This allows the load and any electrical controls to be electrically isolated from the array for servicing. If the system has a controller that boosts current, an overcurrent device may be needed in the wiring to the load, unless that wiring is sized at least 125 percent of the maximum available current that can be supplied by the controller to the load.

Normally, overcurrent protection is not allowed in conductors that are grounded. If a fuse or breaker were used in a grounded conductor and that device opened (due to an overcurrent situation), the normally grounded conductor might become energized (hot) and pose a safety hazard. In the U.S., with our grounded electrical systems, the white marking on a conductor indicates that the conductor is grounded. This means it has no potential difference (voltage) with respect to other grounded conductors or surfaces. When such a marked conductor is accidentally allowed to become ungrounded or even carry voltages above ground, it may damage equipment or harm people.

Only in the case of load circuits is the use of an overcurrent device allowed in a grounded conductor. It is allowed only when the device is one pole of a ganged, multipole circuit breaker that disconnects all conductors of a circuit when it trips.

Where Are Overcurrent Devices Required?

In systems that have sources of available energy that can deliver currents that exceed the ampacity of the conductors, overcurrent protection is required for all ungrounded conductors. Medium-to-large PV arrays

that have more than one string of modules connected in parallel would be such a source.

Conductors in most power systems are sized at 125 percent of the continuous currents they are expected to carry. So it doesn't take much of a source to provide sufficient overcurrents to damage these conductors. Batteries can provide tens of thousands of amps into short circuits. Utility grids can also deliver tens of thousands of amps. With conductors rated to carry from a few to several hundred amps, it is easy to see how they could be damaged.

Again, PV source and output circuit conductors are sized to carry 156 percent of the module short-circuit current. But two or three parallel strings of modules can deliver currents in excess of the ampacity of the rating of the string conductors when a short circuit occurs.

The *National Electrical Code (NEC)* allows 12 volt and some 24 volt PV systems to be ungrounded. A grounded system is defined as an electrical system where one of the circuit conductors is grounded. Of course, an equipment-grounding system and a grounding-electrode system are required on all PV systems at any voltage.

Ungrounded systems require overcurrent protection in both of the ungrounded conductors of each circuit, which may increase the cost and complexity of the system. Faults can occur in either of the ungrounded conductors to ground or between the two conductors. So the *NEC* has always required overcurrent protection (and disconnects) in all ungrounded conductors for safety and for fire hazard reduction.

Another requirement for overcurrent protection has to do with protecting a PV module from reverse currents. Modules have internal connections between the cells that have a certain ampacity. As part of the module testing and listing process, the maximum value of reverse current that the module can withstand under fault conditions is determined. The value of the required series fuse is marked on the back of the module.

This overcurrent device (it may be a circuit breaker) is only indirectly required by the *NEC* through the code requirement that all instructions furnished with a listed product be followed. Only one of these series protective overcurrent devices is required per series strings of modules, and it should be located at the end of the string that is most distant from the ground connection (usually the positive end).

To provide maximum protection for the longest runs of conductors, overcurrent devices are required to be located at or very close to the source of any potential high short-circuit or fault currents.

Battery Circuits

Suppose that a specific battery can deliver a maximum of 320 amps continuously to an inverter under normal operations. The cable from the battery to the inverter would have an ampacity of 400 amps (125 percent of 320). It would be protected with a 400 amp overcurrent device. From an overcurrent protection standpoint, it would be ideal to locate the overcurrent device at the positive terminal of the battery. However, battery acid, hydrogen gas, and sore backs from bending over to check the device preclude the installation this near the source.

Although the *NEC* does not specify the distance, it is generally agreed that a distance of 4 to 5 feet (1.2–1.5 m) from the battery enclosure to the disconnect/overcurrent protection is acceptable. Power centers are listed by the testing organizations with 4 to 5 feet of cables between the main disconnect and the battery. Of, course, these unprotected cables should be of high quality and should be physically protected by installing them in conduit.

If the inverter also serves as a battery charger, it may also be considered as a source of potential fault currents into these same battery-to-inverter cables. In many cases, however, the maximum continuous inverter charging currents are less than the currents the inverter draws when acting as an inverter. If this is the case, the cables have been sized for the higher currents, and no overcurrent protection is required at the inverter end of these cables.

If, on the other hand, the inverter can provide battery charging currents that are as high or higher than the ampacity of the cable, an overcurrent device must be located at the inverter end of the cable. This would be particularly true if the cables were longer than the 4 to 5 feet mentioned above. In many systems, a single circuit breaker, located adjacent to the inverter, provides some degree of overcurrent protection and serves as the battery disconnect.

In other systems where the inverter and batteries are located in two different rooms or more than 4 to 5 feet apart, a disconnect and an overcurrent-protection device may be required at both ends of the battery-to-inverter cable. In a grounded system, the devices are located only in the positive conductor (assuming a negative grounded system). There would be no disconnects or overcurrent protection located in the grounded conductor.

Since batteries can deliver very high currents into faults, overcurrent devices in these circuits must have high interrupt ratings. Typically, current-limiting fuses have sufficient interrupt ratings (20,000 amps or higher) to

successfully open under fault conditions. High-quality circuit breakers by Heinemann, AirPax, and others also have the necessary high interrupt capabilities (25,000 amps) for use in these circuits. Current-limiting fuses should be used when downstream switchgear, overcurrent devices, and other components that might be involved in the fault have insufficient interrupt ratings to withstand the short-circuit currents at their locations in the circuit.

PV Module Circuits

Any time circuits are combined in parallel, such as in module combiner boxes, the conductors normally change size because the output circuits must handle higher currents than the input circuits. As the conductors change size (and ampacity), the overcurrent protection must change to match the new ampacity.

Let's look at a system with four PV module source circuits with a module Isc of 4 amps. The value of the maximum module protective fuse marked on the back of the modules is 15 amps. The conductors in this module source circuit must have an ampacity of at least 1.56 times the short-circuit current (1.56 x 4). This is 6.24 amps (let's round this up to 7 amps) after any temperature or other derating.

Each of these PV source circuits is fed into a fused combiner box, and 8 amp fuses are used in each circuit, since 7 amp fuses are hard to find. If we are using 8 amp fuses, the cable ampacity after deratings must be at least 8 amps. Since 8 amps is less that 15 amps, these fuses can also serve as the module protective fuses while providing overcurrent protection for the cables.

What is the source of potential overcurrents? In this case, the currents may come from the battery, or from any three of the other source circuits feeding currents into a fault in the fourth source circuit. For this reason, the fused combiner box is located where the module strings come together, and where the combined outputs require a larger output cable from the fused combiner box.

This location may be near the modules, which allows the use of short, small module interconnection wiring, but requires longer, heavier fused combiner box output conductors. It may also be located near the charge controller. This requires longer, small module interconnections, but allows a short output cable. Voltage drops, conductor costs, and physical limitations will determine where the fused combiner box is installed.

The output cable must have an ampacity sufficient to handle the combined outputs of all four module source circuits. In this case, it would be 24.96 amps (4 x 1.56 x 4), which we'll round up to 25 amps. A fuse or circuit breaker at the input to the charge controller is required to provide overcurrent protection for this cable from potential overcurrents from the battery. The size of the fuse would be equal to or less than the ampacity of the cable it was protecting, and must be at least 25 amps (again, 4 x 1.56 x 4).

Figure 1 shows module source circuits combined into subarrays and then into a full PV array, using fuses and circuit breakers. Each overcurrent device is rated to carry continuous currents at only 80 percent or less of the rating. Temperature and other deratings for the conductors are not shown.

Figure 1

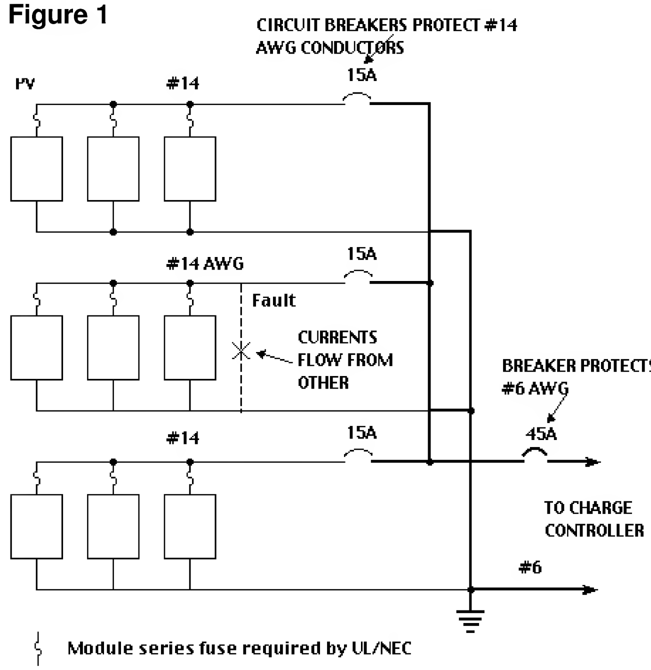
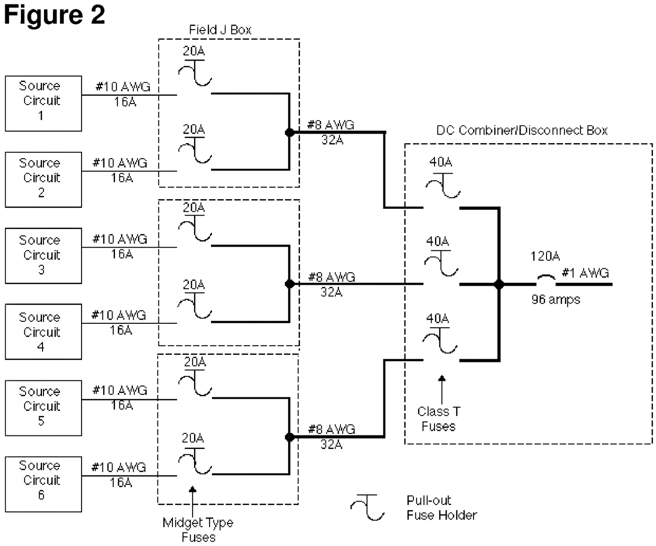


Figure 2 shows a slightly more complex system to further demonstrate the concepts. The currents shown are 1.25 Isc for each circuit, and that represents the continuous current in that circuit. The circuit breakers are increased another 125 percent above this value to ensure that they are operating at only 80 percent of rating on a continuous basis. The figures show how PV source circuits combine, and how the overcurrent devices must increase in size to handle the combined currents and protect the larger conductor wire sizes.

Summary

Overcurrent devices are normally required to protect all ungrounded conductors from current levels exceeding the rated ampacity of the circuit. Either fuses or circuit breakers may be used, depending on the application. The overcurrent devices are rated at or below the ampacity of the conductors being protected, and are

Figure 2



normally sized to carry currents at only 80 percent of rating. In the next *Code Corner,* I'll look at additional requirements for overcurrent devices.

Questions or Comments?

If you have questions about the *NEC,* or the implementation of PV systems that follow the requirements of the *NEC,* feel free to call, fax, e-mail, or write me. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under contract DE-FC04-00AL66794. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

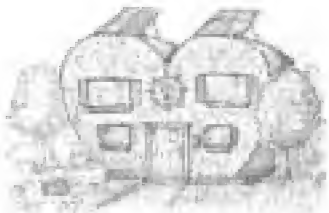
Access

John C. Wiles • Southwest Technology Development Institute, New Mexico State University, Box 30,001/ MSC 3 SOLAR, Las Cruces, NM 88003 • 505-646-6105 Fax: 505-646-3841 • jwiles@nmsu.edu www.nmsu.edu/~tdi/pv.htm

Sponsor: Sandia National Laboratories, Ward Bower, Department 6218, MS 0753, Albuquerque, NM 87185-0753 • 505-844-5206 • Fax: 505-844-6541 wibower@sandia.gov • www.sandia.gov/pv

The 1999 *NEC* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA), 11 Tracy Drive, Avon, MA 02322 • 800 344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301 custserv@nfpa.org • www.nfpa.org

Home & Heart



Kathleen Jarschke-Schultze

We are definitely experiencing the drought here at Casa Schultze. We lost our hydropower about a month ago. We pump water from the creek for our garden. Now we can only pump in the morning, before the pool we pump from goes dry. So far, it refills at night, but with this dry, hot wind every day, even that water source will not last long.

We keep one 1,350 gallon (5,110 l) water tank full, in case of fire. Our other tank, the same size, is filled (and I use the term loosely) from the creek and used on the fruit trees, garden, grape arbor, and perennial plants. We have changed as many plants to drip lines as we can. Now all others must be hand watered—no more overhead sprinkling. Our house water system is from a spring, which dried up in the drought of 1991. That was when we drilled a well. It looks like we will be on well water for everything soon.

Warm Swarm

Until recently, I had five bee hives. Now I have six. Bob-O came in from work one warm spring evening and said, “Did you know we have a swarm out here?” Well, I didn’t know. He and I donned our bee suits, got some ladders, and retrieved the swarm. I held onto the branch while Bob-O sawed it off. Then I climbed down the ladder and shook the bees into a hive body I had waiting close by. They went willingly.

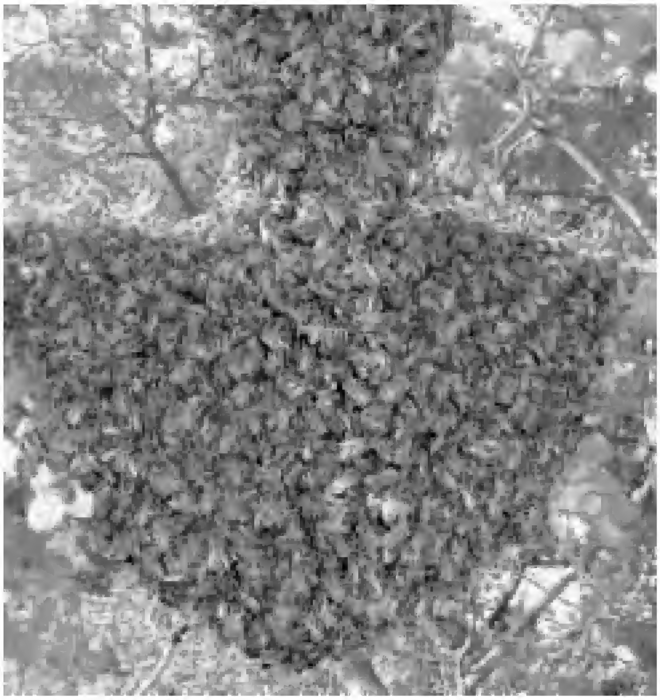
The swarm had come from one of my very first hives. It’s my guess that the hive swarmed because of the windy conditions on our hillside. Being a novice, I had placed my first hives in a good place for sun, but a totally rotten place for wind. This particular hive had always struggled against the wind. Although it survived, it never did well.

A swarm will leave the hive with roughly half or more of the resident bees and the old queen. The swarm is made up of a mixture of old and young bees. The remaining bees and the new queen have to build their population back up, but their comb is drawn (already built), and they have some honey and pollen stored. A vigorous, young queen can keep her nurse bees busy tending her new brood.

I saw a chance to correct my error in hive placement. Two days after we found the swarm, I moved the swarm hive, in the new hive body, to a friend’s house on the Klamath River. I talked another friend into letting me bring the old hive off the hillside, to work his blackberry thicket. The thicket is at least 50 by 20 foot (15 by 6 m). He was going to cut it down. Then he found that an array of bird species used it for nesting. So he left it alone. After my bees crop the blackberries, I will bring them home and put the hive in the beeyard proper.

My beeyard is now downwind in our canyon, beyond our large storage building and several smaller outbuildings that block the wind. Three sides are bordered by an old wooden corral, a large wooden gate, and a huge loading chute for cattle. The fourth side, down canyon, is fenced with 6 foot (1.8 m) high hog wire.

This cool little PV powered fan helps bees beat the heat.



Kathleen's runaway swarm buzzing in the tree.

The bee queen with her branch full of bees.

3 Feet, 3 Miles

I couldn't just move the old hive from the windy place to the beeyard, since bees have a peculiar habit. You can move bees 3 feet (0.9 m) or 3 miles (5 km). If you move them any distance in between, they will return to the place of the old hive and die from exposure.

The old hive was up a hillside too steep to drive. I took all my bee gear there in a wheelbarrow. Usually the two deep supers filled with bees and honey are too heavy for me to pick up, put in the wheelbarrow, and get down the hill. But since it was fairly early in the season when they swarmed, the hive bodies were still light. Not so much honey; not so many bees.

I took off the medium supers, used for collecting surplus spring honey, and extracted what was in them. After moving the hive to the blackberry patch, I returned the extracted comb supers to the top of the hive. The bees will clean the comb and start filling the supers with blackberry honey. First though, they fill any comb in the deep supers not used for brood with honey for their winter food. I love my bees. I never run out of fascination for their behavior. It's like having an ongoing biology experiment in my yard.

Solar Bees

One of my bee magazines advertised a solar powered hive cooler. In hot weather, the bees expend a lot of energy and time cooling their hive. Worker bees that would otherwise be gathering honey are positioned at the entrance, fanning their wings to facilitate air movement in the hive. This cools the hive, and helps evaporate and concentrate the nectar into honey.

I knew I could make a cooler, so I did. I ordered a shallow super, the kind usually used for comb honey production. It is standard Langstroth size, but only 4-3/4 inches (12 cm) deep. Before I glued and nailed it together, I had Bob-O cut three, 2-1/2 inch (6.4 cm) holes in one short side with a hole saw.

I used an inside cover, with a hole cut in the center to hold a small 12 VDC muffin fan. I placed some window screen on the hole before attaching the fan to keep the bees from going into it. I cut a small groove in the edge of the super to snake out the wires from the fan. Wood glue secured the completed fan and cover to the bottom of the super. I also glued window screen over the three exhaust holes on the side.

I placed the whole assembly on top of the two medium supers that topped one of my hives in the beeyard. I picked this particular hive for the experiment because the front of the hive always had a lot of bees on it in the heat of the day. The order of the hive from bottom to top is bottom board, two deep hive bodies, a queen excluder, two medium supers, the solar air exchanger, and finally the outside cover.

After placing the unit on the hive, I hooked up a small, 2 watt solar panel with alligator clips to the fan wires. It worked, and quietly too. The air is drawn into the hive

entrance above the bottom board, moves up through the hive bodies and supers, goes through the fan, and is exhausted through the vent holes on the side of the unit. The air from the vent holes smells wonderful.

The bees seem to appreciate the help ventilating their hive. They no longer mass on the outside on hot days. We'll see how their honey production compares with the other hives in the same beeyard.

Glad Rag

Our friend, Bob Maynard, wanted to send me a dishcloth. He said, "This is the most expensive dishcloth you will ever buy, but you'll love it." Now I know I have a tendency to wax enthusiastic about many things. I am easily pleased and amused, but a dishcloth? Bob said, "I cooked bacon, wiped up the bacon grease on the stove, and then cleaned my glasses with the same cloth." Does that sound like a testing challenge or what? I told him to send me one.

The brand name is Mystic Maid, and it is a microfiber cleaning cloth. It was originally developed for "clean room" applications in the semiconductor industry. The cloth is made from soft, woven microfibers that are split many, many times to create an increased surface area with millions of tiny hooks and channels.

The best thing about this cloth is that you do not need any cleaning agents with it. You get the cloth wet with plain water, wring it out as much as you can, and use it. No soap, no detergents, no chemicals—just plain water.

You can use it dry for dusting, and as an antistatic cloth. You can clean CDs, DVDs, or your eyeglasses with it and it won't scratch them. To clean the cloth, just put it in with your regular cold water laundry. Let it air dry. Don't use fabric softeners or bleach on it.

The Bacon Test

When I got the cloth, I got it wet and wrung out as much water as I could. I had fried bacon that morning on my black enamel stove. It was very messy and greasy. I usually use a spray cleaner to clean up that kind of mess.

I used the cloth on the whole top of the stove, the oven door, the chrome trim—everything. I thought I'd be smearing grease everywhere, but I wasn't. It actually worked. There were some wipe marks, but they disappeared within seconds. I pulled my finger across the recently cleaned surface. It squeaked.

I've had the cloth a couple of months now, and have used it frequently. I've washed the cloth many times, and it still does what it claims. The reduced use of cleaning chemicals in my house pleases me immensely. Viva la technology!

Access

Kathleen Jarschke-Schultze is anticipating poultry keeping at her home in Northernmost California, c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • kathleen.jarschke-schultze@homepower.com

Mystic Maid cleaning cloth distributed by Castle International, 10120 SW Nimbus Ave., Suite C/7, Portland, OR 97223 • 877-468-0888 or 503-624-9327 Fax: 503-624-8471 • info@mysticmaid.com www.mysticmaid.com • Available for US$10 each from Energy Outfitters, PO Box 1888, Cave Junction, OR 97523 • 541-592-6903 • Fax: 541-592-6747 sales@energyoutfitters.com • www.energyoutfitters.com

HAPPENINGS

INTERNATIONAL

Free instructions, photos, drawings, & specs to build solar cookers & water systems with local materials, purchased with local currency. Sunstove, www.sungravity.com

Green Empowerment finances microhydro & other RE projects in Nicaragua, the Philippines, & Borneo. Volunteers needed. www.greenempowerment.org

Solar On-Line Internet courses. Year-round. PV Technology & Opportunities; PV Systems Design Basics; PV Systems Design: Professional; Solar Homes: Healthy Buildings; Solar Energy for Global Development. SóL, PO Box 217, Carbondale, CO 81623
Fax: 559-751-2001 • SoL@SoLenergy.org
www.SoLenergy.org

CANADA

Microhydro Courses: Covers MH systems from 35 W to 100 KW; both battery-based and AC-only; stand-alone or grid-tied. Learn to assess a stream, determine project feasibility, & design & install a system. US$80 to US$160. Prince George, BC. Oct. 26–28, '01, College of New Caledonia, 250-561-5801. Nelson, BC Apr. 26–28, '02, Selkirk College, 250-352-6601. Kamloops, BC, May 10–12, '02, Univ. College of Cariboo, 250-828-5039. Info: www.energyalternatives.ca/mhcourse.htm

Alberta Sustainable House; open house 3rd & 4th Saturdays, 1–4 pm. Cold-climate features & products for health, environment, conservation, RE, recycling, low energy, self-sufficiency, appropriate technology, autonomous & sustainable housing. Free. 9211 Scurfield Dr. NW, Calgary, AB T3L 1V9 Canada
403-239-1882 • Fax: 403-547-2671
jdo@ucalgary.ca • www.ucalgary.ca/~jdo

The Institute for Bioregional Studies demonstrates & teaches ecologically oriented, scientific, social, & technological achievements. IBS, 393 University Ave., Charlottetown, PEI C1A 4N4 Canada
902-892-9578

Vancouver Electric Vehicle Association. Call for meeting info. PO Box 3456, 349 West Georgia, Vancouver, BC V6B 3Y4 Canada • 604-878-9500
info@veva.bc.ca • www.veva.bc.ca

INDONESIA

Nov. 7–10, '01; RE Indonesia, Jakarta. Part of Electric Indonesia trade show. Overseas Exhibition Services, 11 Manchester Sq., London, U.K. W1M 5AB
+44 (0)20 78622090/2000
Fax: +44 (0)20 78622098/2001
indonesia@montnet.com
www.montnet.com

JAPAN

Nov. 11–16, '01; Enviro Shiga 2001. Nagahama Dome, Shiga, Japan. Int'l. environmental business exhibition, incl. RE, water conservation, waste reuse & recycling, environmental monitoring, & environmentally sound products. Shiga Env. Business Exhibition Assoc., Shiga Pref. Gove Bldg. 4-1-1, Kyomachi, Otsu City, Shiga, 520-8577, Japan
+81-77-528-3793 • Fax: +81-77-528-4876
www.pref.shiga.jp/event/messe

NICARAGUA

Jan. '02, Nicaragua. Intro to PV for developing countries, course offers lectures, field experience, & eco-tourism. Taught in English by Dr. Richard Komp & Professor Susan Kinne. US$850. Contact Barbara Atkinson, 215-942-0184
lightstream@igc.org
www.grupofenix-solar.org

SPAIN

Oct. 29–31; First International Conference on Solar-Electric Concentrators, Marabella, Spain. Technical discussions of achievements in concentrating solar electricity, primary emphasis on PV. Contact: Robert McConnell, NREL, 617 Cole Blvd. Golden, CO 80401
303-384-6419 • Fax: 303-384-6481
robert_mcconnell@nrel.gov
www.nrel.gov/icsec

NATIONAL U.S.

Oct. 14, '01; Elfin Permaculture's Permaculture Design Course Online. Runs about six months; includes reading, e-mail lectures, e-mail discussion, and student reports. By Dan and Cynthia Hemenway of U.S., Willem Smuts of S. America, and Tim Packer of New Zealand. Info: BarkingFrogsPC@aol.com
http://barkingfrogspc.tripod.com/frames.html
www.permaculture.net/~EPTA/Hemenway.htm

Pollution prevention video series. Appalachia: Science in the Public Interest offers 42 videos, incl. Solar Dry Composting Toilets, Solar Hot Water Systems, PV, Solar Space Heating, Solar-Powered Automobiles, Quilted Insulated Window Shades, & more. US$25 + S&H, broadcast-quality tapes available. ASPI Publications, 50 Lair St., Mt. Vernon, KY 40456 • 606-256-0077
Fax: 606-256-2779 • aspi@kih.net
www.kih.net/aspi

American Wind Energy Association. Info about U.S. wind industry, membership, small turbine use, & more • www.awea.org

State financial & regulatory incentives for RE: reports. North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695
919-515-3480 • Fax: 919-515-5778
www.ncsc.ncsu.edu/dsire.htm

Energy Efficiency & Renewable Energy Clearinghouse (EREC): Insulation Basics (FS142), New Earth-Sheltered Houses (FS120), PV: Basic Design Principles & Components (FS231), Cooling Your Home Naturally (FS186), Automatic & Programmable Thermostats (FS215), & Small Wind Energy Systems for the Homeowner (FS135). EREC, PO Box 3048, Merrifield, VA 22116 • 800-363-3732
TTY: 800-273-2957
energyinfo@delphi.com
www.eren.doe.gov

Energy Efficiency & Renewable Energy Network (EREN): links to gov. & private internet sites & "Ask an Energy Expert" online questions to specialists.
800-363-3732 • www.eren.doe.gov

Green Power Web site: deregulation, green electricity, technology, marketing, standards, environmental claims, & national & state policies. Global Environmental Options & CREST
www.green-power.com

National Wind Technology Center. Assisting wind turbine designers & manufacturers with development & fine tuning. Golden, CO • 303-384-6900
Fax: 303-384-6901

Sandia's Stand-Alone Photovoltaic Systems Web site: design practices, PV safety, technical briefs, battery & inverter testing, www.sandia.gov/pv

Solar Energy & Systems. Fundamentals of Small RE: Internet college course. Weekly assignments reviewing texts, videos, WWW pages, & e-mail Q&A. Mojave Community College • 800-678-3992
lizcaw@et.mohave.cc.az.us
www.solarnmc.mohave.cc.az.us

Federal Trade Commission (free pamphlets): Buying an Energy-Smart Appliance, Energy Guide to Major Home Appliances, & Energy Guide to Home Heating & Cooling. Energy Guide, FTC, Rm 130, 6th St. & Pennsylvania Ave. NW, Washington, DC 20580 • 202-326-2222 TTY: 202-326-2502 • www.ftc.gov

Solar Curriculum for schools. Six week science curriculum or individual sessions. Free! Over 30 classroom presentations & demos using free or low-cost materials. Susan Schleith, Florida Solar Energy Center • 321-638-1017 www.fsec.ucf.edu

ALABAMA
Centre, AL. The Self-Reliance Institute of NE Alabama seeks people interested in RE, earth-sheltered construction, & other self-reliant topics. SINA, 6585 Co. Rd. 22, Centre, AL 35960

ARIZONA
Apr. 19–21, '02; Arizona Renewable Energy Expo; Prescott Valley, AZ. Educational aimed toward consumers, educators, contractors, youth, and public. Info: Prescott Valley Economic Development Found., 888-240-4256 www.pvedf.com

Glendale & Scottsdale, AZ. Living with the Sun: Lecture series by AZ Solar Energy Assoc. History & current overview of concepts, design, applications, & technologies on solar heating/cooling, architecture, landscaping, PV, & cooking. 7–9 pm, 1st Wed. of month at Glendale Foothills Branch Library, & 3rd Tues. of month at Scottsdale Redevelopment & Urban Design Studio. Jim Miller 480-592-5416

Tax credits for solar in AZ. ARI SEIA 602-258-3422

ARKANSAS
Sun Life Constr. by Design: Seminars 3rd Sun. of month. Hands-on, incl. ferro-cement, building dwellings for minimal materials expense. Loren Impson, 71 Holistic Hollow, Mt. Ida, AR 71957 870-867-4777 • loren@ipa.net www.Sun4Life.com

CALIFORNIA
Oct. 20, '01; Solar Cooking Summit, Agua Caliente Park, San Diego County, CA. Boiling Water Recipe Contest, share info & technical innovations, solar oven building classes. For event questions or rule list, contact Ian Zalewski, boilingwatercontest@spreemail.com

Nov. 1–2, '01; International Symposium on Distributed Energy Resources; San Diego, CA. Betsie Brown, 858-794-7355 betsie@brownbostwick.com

Nov. 10, '01; Pomona, CA. 2001 Southern California RE Expo, Pomona Fairplex. Exhibits, workshops, manufacturers, & vendors for wind power, EVs, inverters, solar cooking, solar pumping, green building, strawbale, solar electric, solar thermal, net metering, hydropower, fuel cells, & more. 888-647-6527

Dec. 11–14, '01; Sacramento, CA. EVAA Electric Transportation Industry Conference. Battery EVs, hybrids, path to commercialization. 650-365-2667 www.evaa.org

Arcata, CA. Campus Center for Appropriate Technology, Humboldt State University. Ongoing workshops & presentations on alternative, renewable, & sustainable living. CCAT, HSU, Arcata, CA 95521 • 707-826-3551 ccat@axe.humboldt.edu www.humboldt.edu/~ccat

Rebates for PV & wind. CA Emerging Renewables Buydown Program, CA Energy Comm., 800-555-7794 or 916-654-4058 CallCntr@energy.state.ca.us www.energy.ca.gov/greengrid

Energy Efficiency Building Standards for CA. CA Energy Comm. 800-772-3300 www.energy.ca.gov/title24

COLORADO
Carbondale, CO. SEI: hands-on workshops. 1–2 week sessions. PV Design & Installation, Advanced PV, Wind Power, Microhydro, Solar Cooking, Environmental Building Technologies, Solar Home Design, & Straw Bale Construction. Solar Energy International (SEI), PO Box 715, Carbondale, CO 81623 • 970-963-8855 Fax: 970-963-8866 • sei@solarenergy.org www.solarenergy.org

IDAHO
Oct. 26, '01; 1st Annual Idaho Energy Fair. Sun Valley's Elkhorn Resort. Displays, workshops and demonstrations. Contact: Linda, Blaine Soil Conservation District, 119 North River St., Hailey, ID 83333 208-788-2254

IOWA
Prairiewoods & Cedar Rapids, IA. Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. All welcome. Call for schedule changes. IRENEW, PO Box 355, Muscatine, IA 52761 • 319-288-2552 irenew@irenew.org • www.irenew.org

KANSAS
Oct. 22–27, '01; Matfield Green, Matfield Green, KS. Women's Wind Power workshop. Wind system design, components, site analysis, system sizing, and a hands-on installation of a full-size wind turbine and tower. US$550. Solar Energy International. See "COLORADO" for SEI access.

KENTUCKY
Livingston, KY. Appalachia: Science in the Public Interest. Projects & demos in gardening, solar, sustainable forestry, more. ASPI, Rt. 5, Box 423, Livingston, KY 40445 • Phone/Fax: 606-453-2105 aspi@kih.net • www.kih.net/aspi

MASSACHUSETTS
Greenfield Energy Park needs help preserving the historic past, using today's energy & ideas, creating a sustainable future. Greenfield Energy Park, NESEA, 50 Miles St., Greenfield, MA 01301 413-774-6051 • Fax: 413-774-6053 nhazard@nesea.org • www.nesea.org

MICHIGAN
Tillers International, classes in draft animal power, small farming, blacksmithing, & woodworking. 5239 S 24th St., Kalamazoo, MI 49002 616-344-3233 • Fax: 616-344-3238 TillersOx@aol.com www.wmich.edu/tillers

MINNESOTA
'01 MREA Workshops. See "WISCONSIN"

MONTANA
Whitehall, MT. Sage Mountain Center: one-day seminars & workshops, inexpensive sustainable home building, straw bale constr., log furniture, cordwood constr., PV, more. SMC, 79 Sage Mountain Trail, Whitehall, MT 59759 Phone/Fax: 406-494-9875 cborton@sagemountain.org

NEVADA
Jun. 15–19, '02; Solar 2002: Sunrise Sustainability Expo. Reno, NV. Annual American Solar Energy Society conference. ASES, 2400 Central Ave. #G-1, Boulder, CO 80301 • 303-443-3130 Fax: 303-443-3212 • ases@ases.org www.ases.org

NEW HAMPSHIRE
Spinning a Web of Solar Spirits; workshops on living with the sun. 1st Wed. every month. Sunweaver, 1049 1st, NH Turnpike, NH 03261 • 603-942-5863 Fax: 603-942-7730 • fonature@tiac.net

NEW MEXICO
Oct. 4–6, '01; Photovoltaic System Installation course, Albuquerque. A hands-on, how-to course. Supplement distance learning with practical hands-on skills. Solar-on-Line. See "International" for access info.

NORTH CAROLINA
Saxapahaw, NC. How to Get Your Solar-Powered Home: Seminars 1st Sat. each month. Solar Village Institute, PO Box 14, Saxapahaw, NC 27340 • 336-376-9530
Fax: 336-376-1809 • solarvil@netpath.net

NEW YORK
Tax credits. Info on grid connection & tax credits: NY State PSC, www.dps.state.ny.us/photovoltaic.com

Loan fund. Info on low interest financing for RE: NY Energy $mart Program, NY State Energy R & D Authority
518-862-1090 ext. 3315
Fax: 518-862-1091 • rgw@nyserda.org
www.nyserda.org

OHIO
Perrysville, OH. RE classes: 2nd Sat. each month. Straw bale class 3rd Saturday, through Sept. Solar Creations, 2189 SR 511 S., Perrysville, OH 44864
419-368-4252 • www.bright.net/~solarcre

OREGON
Nov. 3, '01; EORenew Annual Meeting. John Day, OR. Elections, program, summary of the year's events. EORenew, PO Box 485, Canyon City, OR 97820
541-575-3633 • info@solwest.org
www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 8 wks., 4 interns per quarter. Aprovecho Research Center, 80574 Haxelton Rd., Cottage Grove, OR 97424 • 541-942-0302 • dstill@epud.org
www.efn.org/~apro

RHODE ISLAND
Energy Co-op provides RE, energy efficiency & conservation services, & group purchases of "Energy Star" products. Erich Stephens • 401-487-3320
erich@sventures.com

TENNESSEE
Summertown, TN. Kids to the Country: nature study program for at-risk urban TN children. Sponsors & volunteers welcome. The Farm, Summertown, TN 38483
931-964-4391 • Fax: 931-964-4394
ktcfarm@usit.net

TEXAS
El Paso Solar Energy Association bilingual Web site. Info in Spanish on energy & energy saving. www.epsea.org

El Paso Solar Energy Association: meetings normally held 1st Thur. each month. EPSEA, PO Box 26384, El Paso, TX 79926 • 915-772-7657
epsea@txses.org
www.epsea.org

Houston Renewable Energy Group: meets last Sun. of odd months at TSU Engineering Building, 2 PM. HREG, PO Box 580469, Houston, TX 77258
jferrill@ev1.net
www.txses.org/hreg/HREGhome.htm

WASHINGTON STATE
Oct. 11–14, '01; Guemes Island, WA: Microhydro workshop. Class & labs followed by tours, incl. Canyon Industries, turbine manufacturer. US$400. See "COLORADO" for SEI access • Local coordinator: Ian Woofenden, PO Box 1001, Anacortes, WA 98821
360-293-7448 • Fax: 360-293-7034
ian.woofenden@homepower.com

Oct.15–20, '01; Guemes Island, WA: PV Design & Installation workshop, with Windy Dankoff. Site analysis, system sizing, equipment, appliances, demonstrations, lab exercises, & a complete hands-on installation. US$550. See "COLORADO" for SEI access. See above for local coordinator.

Oct. 22–27, '01; Guemes Island, WA: Build Your Own Wind Generator workshop, with Hugh Piggott of Scoraig Wind Electric, Scotland. Hands-on, shop workshop, constructing wind generators from scratch. US$550. See "COLORADO" for SEI access. See above for local coordinator.

WISCONSIN
MREA Workshops: Oct. 6 Basic Photovoltaics Custer, WI. Oct. 7, Intermediate PV, Custer, WI. Oct. 20 Home Weatherization Techniques Custer, WI. Nov. 10, Masonry Heaters Intro, Custer, WI. Nov. 26–30, RE for the Developing World, Custer, WI. Call for cost, instructors, & more info. Significant others half price. MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595
Fax: 715-592-6596
mreainfo@wi-net.com • www.the-mrea.org

the Wizard speaks...

Energy Futures

At the present rate of use, all recoverable reserves of fossil fuels will be gone in less than 400 years. With increased use, they could be gone in less than 100 years. Nuclear fission is too dirty and dangerous to be an option. Nuclear fusion uses up hydrogen in a nonrenewable manner. Even in the absence of environmental factors (there are many, as we all know), a solution needs to be found.

Considering all factors, solar and wind power sources are the best bet for the immediate future. These could be backed up by fuel cells, running on stored hydrogen. The hydrogen would be produced by solar and wind. There are still problems with this approach, but it is viable for the near term.

Some interesting possibilities may exist for the long term. They are all concerned with the electromagnetic control of the energy of space (the zero point field). This control would provide a continuous and unlimited source of energy, as well as control of gravity. Thus, we could have "free energy" and antigravity. As an added bonus, this could also provide us with the freedom to explore and colonize the solar system. In some off-planet applications, nuclear energy might be acceptable.

The future is not as bleak as some predictions indicate. We still have time to change our path. However, we must begin that choice now, or be locked into a progression that we surely do not want. Begin now.

Pow R. Maker
Sunnyville, Earth

Home Power Letters

P.O. Box 520
Ashland, OR 97520

Errata
We humans at Home Power *have a couple of errors to correct that appeared in* HP84. *We strive for accuracy in our publication because we know you count on us. We apologize for any inconveniences these errors have caused.*

In the Midnight Special *inverter settings table on page 40, the "Set Float VDC" recommended setting for both flooded and sealed cells should be 26.8 VDC. Using the higher stated setting for sealed cells could damage them.*

In the Converting A Flashlight to LEDs *costs and parts table on page 76, the eleven resistors should be valued at 33 Ω and not 330 Ω as originally stated. Fortunately, this mistake will not result in any harm to the flashlight, but will result in significantly reduced brightness.*

Letter to the President
Dear Mr. Bush, We have received our IRS refund check for US$600. We do not think that such refunds are in the best interests of the country, but at least we can ensure that our money will not be spent on further destruction of the air, water, forests, and peace of our planet.

We have donated our tax refund to the [insert your favorite activist organization here]. For many years, this local grassroots organization has worked effectively against pollution, illegal and destructive resource extraction, and other shortsighted activities that harm our environment. Thank you for allowing us to spend our tax money on this worthy cause. Sincerely, [insert your name here]

Solar DHW Primer
Dear Richard, I enjoyed Ken Olson's article entitled *Solar Hot Water: A Primer* in *HP84.* I want to pass by you and Ken a question and an idea on the closed loop antifreeze heat exchanger system.

First, it is not clear to me why both a storage tank and an auxiliary tank are specified. Could we not have just one tank for potable water as shown in the drainback system schematic? This would reduce the volume of hot water stored, but that could be compensated for by using a larger tank.

Second, the problem of high stagnation temperatures could be eliminated or reduced by dumping some of the thermal energy in the closed loop just after it leaves the heat exchanger. What about passing the heat from the loop through a thermovoltaic device? I know nothing about these except that, some years ago, there was a wristwatch for sale that powered itself by using the temperature difference between the skin and the ambient air. The cool side of the device in our application could be cooled via a finned heat dissipater and fan when needed.

If thermovoltaics are not practical, the heat could be wasted by passing the liquid through an automobile radiator. When the temperature is too high, a fan would blow across the radiator, dissipating heat. Or we could get more esoteric and stop the "problem" at its source by using a collector glazing that would darken when a voltage was applied. I look forward to hearing your opinions. Regards, Tom Medill • tpm5@psu.edu

Hi Tom, Thank you for your letter and comments. Solar storage can be handled with either one tank or two tanks. I have shown the single-tank version in two of the drawings and a two-tank version in another. A single oversized tank takes up less room. So why would anyone want to use two tanks?

If your existing water is heated with a gas water heater, the single tank strategy won't work because you need to be able to isolate the solar heated water from the conventionally heated water. You can do that with an electric tank by disabling the lower heating element. But a gas tank heats from the very bottom.

Another reason is that a 120 gallon tank is about the largest stock item available, which means that two-thirds of that (approximately 80 gallons) is the most solar storage you have available. Larger systems will need two tanks. Some people already have a tank, and adding another is perhaps a more convenient approach. Every system is different.

What to do with excess heat? Solar hot water systems are generally sized to meet 100 percent of the load in the summer. Otherwise, excess heat becomes a problem in the summer. There are ways to deal with this, and all of your suggestions may be viable options (although I can't speak from any experience regarding the changing glazing idea). Swimming pools or hot tubs are one of the best ways of dealing with excess heat, because you always have a place to put it. But not everyone has a pool. There is yet another option that I haven't mentioned yet—using the solar storage tank with an on-demand heater. More articles to come. Ken Olson

Texas Net Metering
Dear *Home Power,* A quick note on the power situation in Houston, Texas. Deregulation is about to come into effect. Enron is the current power provider. To get better name recognition in order to try to keep customers from switching to other power companies, Enron spent fifty million dollars for the naming rights to the new baseball field. Of course, the fifty million is coming out of the

pockets of consumers. Enron has raised rates 28 percent in the last year.

Love the magazine. My only suggestion would be to add a regular column on alternative home designs. Thanks, Mike Wood, Kingwood, Texas info@freshairadventures.com

Hello Mike, Thanks for this Texas update. We are trying gradually to publish information about other energy topics such as architecture and solar heating. You may have noticed that there is now at least one solar thermal article in every issue of Home Power. *We'd love to cover energy efficient building also. Readers, send us your solar thermal and energy efficient building articles! Richard Perez*

Net Metering in Montana

Hello Richard, I have been visiting your Web site, and reading as much as I can. I recently saw the article on guerrilla solar about the people that were not hooked up to net metering. Look up www.montanagreenpower.com and look at the Manhattan site. This is my home, and I was the first person to go on net metering in the state of Montana. I went on-line in December of 1999. It took me about six months of talking with lawyers to get the net-metering contract that we had. It was just revised with some minor changes this last month. If anybody has any questions, I would be more than happy to try to answer them.

I am presently supplying about 75 to 80 percent of my energy demand with 24, 100 watt Siemens solar panels and two hydro turbines. I am planning to put up some wind generation this fall. Ed Roe, 2840 East Cedar Meadow Lane, Manhattan, MT 59741 • 406-282-7620 esroe@juno.com

Utility Meter Guesswork

I have read *Home Power* for fourteen months, and liked all the articles that were presented. I am kind of a do-it-yourself person. I chose to go solar and try a small two panel system. I was tired of the electric utility estimating my electric usage, a common practice. So I disconnected from them February through October of last year. It was hard at first, but I learned to adjust my lifestyle and habits.

The big plus was the money I saved. With this I bought batteries, a small inverter, two badly damaged solar panels, and a small used 300 W Chicago generator.

In November, I reconnected to the utility and paid the reconnect fee. The first month, the bill said I used 57 KWH (in two weeks), which was wrong. I said this must be a mistake and asked them to reread my meter. The bill was then $16.90 (minimum service charge). The next month's bill said I had used even more energy (six weeks of service). The bill was again $16.90. The last bill (twelve weeks) was $16.90, and 0 KWH was right (no energy usage).

This test showed a failure of the utility to read the meter and not just guess. You see, I never turned the main disconnect breaker on the house service back on when the service was restored in October (no connection to the utility and a locked main box).

I suggest that you always read your own meter and keep a year or more of records and compare each year. Write it down when you connect something new that was not connected last year, and whether it used more or fewer watt-hours. Do not accept what the little bar graph on the bill said about last year's usage (if you had the same connected load). Check and you will find some interesting information. They should not guess for several months and make you call their hand for service you did not use.

Guerrilla solar is number 1. Keep up the good work, and we can all have a better planet to pass on to the next generation. Alive and free in Arkansas amidst the utilities. Anonymous

After the Last Drop

Dear *Home Power,* Thank you for providing a great resource for information on alternative energy. For the past four years, we have been running our travel trailer at a remote location in Colorado solely on solar electricity. Now that we have moved into a house, we are very interested in seeing an article on solar shingle installation, since we are in a covenant community. We have already installed all Energy Star appliances and compact fluorescent (CF) light bulbs throughout.

Unfortunately, the public still needs to be educated that solar energy is not an eyesore. Solar energy is a display of forward thinking and a true commitment to energy and environmental conservation. I believe that alternative energy production is now a necessity.

Our United States government is so tied into the mentality of fossil fuel and OPEC dependency that they cannot see the end of the supply. When fossil fuel runs out, so will the ability to manufacture goods. This end of supply will devastate the global economy unless the steps are taken quickly to protect an extremely valuable resource.

It's not just the electricity we are in peril of losing. It is the lifestyle that the world population has become accustomed to no matter how much or how little fossil fuel we use. Your magazine has been and will continue to provide us with many ideas on energy alternatives and conservation. Craig Burnes, Firestone, Colorado

Remote Net Metering

In reply to the reader about "3 KWH Per Day" (*HP83,* Letters, page 144) who has little or no sun for most of the winter, I have a solution. Purchase a photovoltaic system anyway to put energy into the power grid. This may sound like double talk, but it could be possible.

I live in southern California and I see so much desert land just collecting dust as solar energy heats up the ground. Is ground available in your vicinity that is above the clouds where a solar-electric system could be placed? Put your PV system on a piece of land where sun shines adequately. The power meter would be located at the PV site for net metering, but in this case only one-way metering, namely into the power grid. At your home in your sun-limited location, your existing power meter would do its normal job.

This same type of placement could be used by anybody that did not want the solar or wind equipment at their home. With a good review of your consumption and a change to energy efficient apparatus, your participation in the energy crunch would be met without the problems of utility-intertie, placement, neighbors, community rules, and security. You would still get a payback for your part in supporting renewable energy by having a PV generating system installed to meet your needs. The system would be installed with optimum placement and equipment. A battery backup system is not needed at the generating location. You can have any backup system at your home location to meet the blackouts that will be inevitable.

The power grid is here to stay. The use of this fairly reliable power source should be continued, but now the participation of small users can be more than a one way street. You now can have your power put into the grid and remove it when needed. If you have the resources to put more power into the grid than you use, you will have the advantage from extra income when your payoff has been met. This investment of your savings may be better than the stock market.

All we need now is a plan blessed by the federal and state governments, power companies, local building codes, and a location to implement the idea. The idea is very feasible because a site like what I propose could be built with volume buying and uniform plans as well as maintained and secured by technicians such as myself to protect each participant's investment. The solar site could be bought and sold like a cemetery plot. Solar sites could be considered agriculture because the land is growing electricity from the sun. Then the many acres of agriculture land not in use could be equipped as solar farms all over the nation. This is a way for a small farm to add to its income by leasing land to grow electricity and by receiving a portion of the generated income. George J. Birds Jr., Lebec, California
birds@inreach.com

Great ideas, George. You'll have an uphill battle with the utilities, but go for it. Folks could also consider putting their money into grid-tied PV systems on the homes or businesses of relatives and friends in sunny areas, or for nonprofit organizations. This can make an environmental contribution, and a variety of financial arrangements could be cooked up.

But while some climates really are not suitable for PVs, I think this is much more rare than generally thought. I live in western Washington, which has a reputation of being very rainy. But I get about half of my electrical energy from PVs, and have for almost 20 years. I like to say of PV and wind output that "you get what you get." We don't try to grow tomatoes outdoors here, but all this moisture sure grows some nice Douglas-fir trees. Spending my time wishing I was in Arizona is counterproductive. Sure, my PVs would do more there, but that's not where I am. If folks would start out with a few panels in their "poor" solar climates, they might be surprised by how much energy they generate. Ian Woofenden

CFs With Good Power Factor

The letter from Eric Kay in *HP84,* page 140 suggests, based on testing one compact fluorescent (CF), that most CFs and electronic ballasts (EBs) have poor power factor (PF). All kinds of things have poor PF, and whatever your system, total harmonic distortion (THD) may be problematic too. But there are many CFs and EBs available with excellent PF and THD. Poor PF is simply not a universal characteristic of CFs. We've tested and found CF products that not only provide excellent PF and THD, but do so while starting outside in our winter weather conditions (north of North Dakota). Peter Kidd, Winnipeg Hydro • PKidd@city.winnipeg.mb.ca
www.city.winnipeg.mb.ca/interhom/pdf/hydro/street_lighting.pdf

Wizard & Population Control

Dear *HP,* I am writing in response to *The Wizard Speaks* column, "Population and Resources" in *HP83.* As I read "overpopulation and overuse of resources is the greatest potential danger for the environment" and "population must be greatly reduced," I was upset to see this reductionist viewpoint printed concerning a very complex issue.

The wizard's article is myopic and offers no solutions, not even an idea to think about. Why print such an article? What it does do, with the openness to interpretation, is align itself closely with the philosophy of many other population reduction groups. A disgusting reality is when you dissect the supporters of "population control" and "immigration control" you find organizations that are openly white supremacist and racist, and you are aligned with them politically.

In the U.S., population control translates to immigration control, since more than 50 percent of growth is from immigration, and that percentage is rapidly growing. Immigration control is an issue that carries a history of division within the environmental movement. Looking in the recent past, it came up for a vote with the members of the Sierra Club, the largest environmental group in the country. Anti-immigration groups spent US$1 million trying to convince members that the Sierra Club should support

U.S. immigration restrictions. Hundreds of people quit over this issue, though the club ultimately voted it down. As a Californian, I have seen how "immigration control" has played out politically, with laws denying health care and education for undocumented human beings, to the increased militarization of the border.

Regardless of whether you're talking about world population control or local immigration control, it is unacceptable to bring up these issues without a political analysis. What does it mean for an American to say population is the number one problem, when Americans, 5 percent of the world's population, consume 30 percent of the world's resources? It means that you are shifting the blame and responsibility for our environmental crisis away from the source (western imperialism, colonization, consumeristic lifestyle) to scapegoat poor people with no political power who are victims of globalization.

This article also made we wonder, what type of population control is being advocated? Multiple events, both historically and presently come to my mind as forms of population control. The holocaust and all ethnic cleansing campaigns have been very effective at controlling the population. So have AIDS, famine, war, and forced sterilization. Due to the state of the world, I honestly cannot rule these out as possible solutions for the Wizard. When you are so shallow in your analysis of the "problem," these types of solutions fit.

This issue is very complex, politically and morally. It is impossible to bring it up in any constructive way without talking about economies, child rearing practices, lifestyles, resource consumption, and technologies used. Laura Allen • lauraa@prisonactivist.org

Hello Laura, I read your letter and read, once again, the column you are objecting to. You grossly misunderstood the subject of this column, which is world wide population control (as in we should be birthing less humans) and natural resources. The column has nothing to do with immigration into the U.S.

I personally agree with your comments on immigration into the U.S. and so does the fellow who writes the Wiz column. You just misunderstood him. The irony of this entire misunderstanding is that the fellow who writes The Wizard *(no name, as he is deeply retired) is from an immigrant family that is part of the most persecuted minority in human history.*

Just for your information, Home Power *is as diverse a crew as you will find anywhere. While we have our share of honkies, this crew contains immigrants, expatriots, and even one fellow (a genetic mixture of Mexican/Yaqui Indian/English) who isn't a U.S. citizen for political reasons.*

The Wiz has the right to discuss this. He has clean hands. He has no children, lives in a 170 square foot cabin heated by wood he gathers by hand, and lives with a small 300 watt PV system. He neither owns nor drives a motor vehicle, and lives on an annual income of less than US$5,000. He is about as far from the "ugly American" as you can get.

Incidentally, as an old Commie myself, I totally agree with and respect your opinions on American imperialism, both economic and political. On a global scale, Americans are the *problem. Richard Perez*

NKF Inverters are Real

The Web info labeled "Guerilla Inverter Still Available" was welcome and intriguing. However I think calling them "guerilla inverters" kind of misses the real interesting potential here. NKF isn't making 100 W tiny, toy inverters for people who want to shake pointy sticks at "the system." They also aren't some hobby house nursing a dying product here (the expectation I had from the letter in *HP*). They are evolving a modular product for consumer systems designed to grow over time, a product to be used in a radically different way than our current generation of fat-budget 5 KW grid-ties. Pretty neat idea, really. In some senses we could be starting into the next logical step *after* the DC-wired RE house gave way to the AC inverted RE house.

The NKF product concept is to take small groups of two to eight PV panels and make them into AC power sources. You'd stop thinking of them as being 12 or 24 VDC, and start thinking of that PV rack as being 115 or 230 VAC. Keeping the power per PV group low means no need for finger-thick cables or expensive DC-rated gizmos, plus the result can be very efficient, true sine-wave AC. No need for expert planning or *Code Corner,* because it's no more complex than the home wiring sold at your local Home Depot. Plus NKF's new generation is a 200 to 500 W waterproof version actually designed to be strapped onto the back of each six to eight panel tracking rack (the upcoming OK5).

Will this approach be cheaper than the big-box central 5 KW or 10 KW grid ties? Well, the answer is based on volume, not material costs. If NKF can make a million+ OK5 units each year, I'm sure the cost per 1 KW will be far less than the current cost using boxes made in the hundreds or thousands each year. It's like the magic of a US$130 PDA (Palm Pilot), which was 1,000 times more complex to design and manufacture than any big-box grid-tie inverter, yet still manages to cost only US$130.

I think anyone seriously hoping *most* California residents will install a 10 KW, US$35,000 grid-tied system is plain looney. As an average working guy in an average suburb with kids in college, I have to lump such a system into the "Gee, won't it be swell" category with power boats and two-seater sports cars.

In contrast, I think expecting most California residents to consider installing a 4 square foot 100 W "micro-grid"

system that evolves over a few years into a 500 W or even a 2 KW system is quite reasonable—*if it were legal and easy to do.* Bundle a 100 W panel with an OK4, and you could sell them at the local Quicky-Mart or 7-Eleven. Picking up such a micro-grid system would cost less than many people spend on their SUV each month. With a mere 300 to 500 watts in micro-grid solar, the average working-person's home could virtually disappear from the utility grid from 9 to 5 each weekday while they're at work.

How to make it legal? Well, don't ask me—I'm just shaking pointy sticks here! I think the guerrilla solar pages in *HP* are a good idea, but I'd treat them a bit more formally. Include the wonderful color system diagrams and bill-of-materials just as you do for "real" systems. The current pages kind of imply "here's a wild-n-crazy prank pulled by these risk-taking kids." *HP* could even add the dumb "don't try this at home" or "professional driver on closed circuit" disclaimer. The only way I see it becoming legal is if a few percent of the people in the U.S. start doing it, and show there's no problem. Having *HP* show the micro-grid systems—"I bought this, I wired it up like this and I'm done, oh, but by the way don't try this at home"—would be a good step in that direction.

I have my small-guy's dream, a US$8,548 PV system all planned and ready to go. But budget realities and a home owners' association (HOA) means I'll probably start with a few NKF micro-grid systems first. I'm also running to join the HOA board/committee. I figure I can plant the seed of group interest *before* I try to apply for my rooftop panels! Best Regards, Lynn August Linse, Foothill Ranch, California • lynn@linse.org

Hello Lynn, That's the spirit! I totally agree and regularly break out a spreadsheet and muse. What would the impact of just a couple of grid connected PV modules on every home have on America's energy grids? I come to similar conclusions as you do. While individually, they make little difference, millions of them make a huge difference. Richard Perez

RE Education in Middle School

Hello Kathleen, I just wanted to let you know how much I enjoyed your article in *HP83.* I teach science to eighth graders, and I guarantee you my kids know about renewable energy. We do a unit on electricity, and most of it is hands-on stuff. We learn the basics, then we set pickles on fire and do some other cool things to show the energy content in electricity. Oh, I forgot—we also read *Home Power.* I'm a subscriber, and I take my collection with me.

We spend three days on renewables, with lessons on solar, wind, and hydro. We have an in-depth discussion about the advantages and disadvantages of all three. This year, I even added hybrid cars and fuel cells.

I start by telling them all about my house and how it is powered by solar modules. You can bet these kids are interested when they find out I am not hooked to the electrical grid. I go through the things you did with the phantom loads and conservation. Finally, everyone tracks his or her energy consumption for a day. They have to find the tag on their appliances, record the watts, and calculate their total energy consumption in watt-hours for a day. They then use our calculations to figure how many modules and batteries they would need to operate their house based on the sun shining one out of every four days. It's not totally scientific, but the kids begin to understand the process of site evaluation.

This is a very enlightening experience for them. Most of them have no clue about RE. I'm sending you a picture of us using two Siemens SP 36 modules wired in parallel to power a 12 volt automotive cooling fan. (I'm the bald guy with a name tag around my neck.) This is a very good lesson. It demonstrates not only solar, but also positive and negative (the fan will go both ways) and parallel circuitry. We then put flashlight batteries together end to end and make the fan go faster and faster. That demonstrates series circuits. My kids know the difference between series and parallel.

Thanks for taking an interest in young people. They aren't as bad as they are made out to be. They are curious, but they need stimulation. Some boring teacher standing up and yammering about electricity or having them read from a book like that fifth grade class just doesn't cut it.

If you are ever in my area in Oconee County, South Carolina, please give me a call at Westminster Middle School. We would love for you to speak to our class. I could provide you with props. Thanks again for a good article, Ed Jarrell • edwin@carol.net

Hi Ed, Thanks for your wonderful letter and all your good work. The more we inspire people to relate to kids and share their knowledge of the world around them, the

better off we all are. Of course I realize I'm preaching to the choir here. I love getting feedback like yours on my column. Thanks for your time, attention, and for being a teacher. Suncerely, Kathleen

Gets a Charge Out of *Home Power*

Dear *Home Power,* After much fruitless searching on the Internet, I finally found what I was looking for on your really useful Web site—a circuit for an electric fence charger. My partner is good at making things and had his own idea on how to put this together, but the circuit diagram on the PDF downloads on your site confirmed his theory.

Hey presto, we now have a working electric fence that is ten times better than the commercial ones available locally (and it doesn't half deliver a jolt even when only turned up a third of the way as I found out the first time we tested it for real).

The garden of our property in England is surrounded by fields that this year are home to a lively bunch of young dairy cattle who have so much grass to eat that they are bored and restless and are more interested in eating our plants and pushing stones out of the wall and generally being a big nuisance! Some electric fencing was in order to keep them away, but buying the whole shebang from the local agricultural suppliers was too expensive an exercise. Since we have installed this fence, the cows are now very wary and the plants and walls have not been touched. Thanks again, Jeanette Chadwick J.Chadwick@staffs.ac.uk

More Fence Charging

Thanks for providing the electric fence schematic and details by designer Richard Perez! I assembled it using junk box items, and bought the 555 chips and the two transistors from a local Radio Shack. My total cost was about US$10. Richard is right, this unit produces *high voltage!* I'm using the unit to protect my sweet corn patch and garden here in rural Ohio. Initially, I was using a car battery for power, but found that a 14 V, 200 mA AC adapter will run it. The unit can be made to jump 1 inch sparks! Steve Reed, Ohio • reed@nfolink.com

Hello Jeanette and Steve, As designer of that electric fence circuit, I am very pleased to hear that it is serving you so well. As you have already discovered, that circuit is capable of delivering substantial shocking power to the fence, so beware! We mistakenly left the charger set on high power once when we reduced the fenced area here, and it literally knocked our horse from her feet.

The icing on this particular cake is that this fence charger is not only super reliable (we ran one here for over six years with no failures), but low in energy consumption. Richard Perez

Expensive, Inefficient Inverters

Dear *Home Power* crew, First let me add my voice to all the thank yous given to the *Home Power* staff over the years. The highlight of my day is finding a new issue of *Home Power!*

But there is one thing that is just driving me crazy! It is the subtle recommendations that keep appearing and reappearing in your articles and editorials, suggesting that big, expensive inverters are the only realistic way to approach the design of a solar-electric system. For example, a quote from your April/May 2001 issue, from the article "How to Choose an Inverter for an Independent Energy System": "There are ways to use DC directly, but for a modern lifestyle, you will need an inverter."

To start, I want to confess that I am an architect. I am not an electrical engineer, master electrician, or electronics technician, and I don't wake up in the morning with an uncontrollable desire to rip apart my house wiring. I also will admit that I live and work in a very confined world, because my architectural specialty is the design of remote cabins, lake cottages, and vacation homes. Each project is a new opportunity, unencumbered by bad choices and commitments from the past—a luxury that I am sure most of your readers do not have. The process is to identify each client's goals and priorities, and especially important, to evaluate individually each client's property. I want the end result to be a total design solution that incorporates aesthetics, functionality, a sensitivity to my client's land, and ideally, total project sustainability.

Many of these projects are off-grid, and some clients even make that choice consciously when they are not. Having said all of this, the purpose of this letter is to find out where my thinking has gone wrong.

In my opinion, the key to making a solar-electric system efficient is the absolute commitment to conservation—I know that you will not disagree with that. Why then would anybody choose an "easy out" design approach, to buy a US$3,000 inverter that wastes at least 20 percent of all the energy that the system is able to collect, just because they can wire their house like "normal" people?

For that matter, I believe that designing and wiring a house like "normal" people is the very heart of the efficiency issue. The best example I can think of, is all of the power-robbing ground fault protection outlets required by the *NEC.* Not just the outlets, but the number of outlets that the *NEC* thinks you must have! Besides the obvious choices of selecting efficient electrical appliances (without phantom loads), heating and cooking with gas (or wood), building with ample insulation, designing for passive solar heating, and incorporating natural daylighting features, it seems to me, the most important next step is to design an *efficient* solar-electric system.

Although I believe my clients should get what they want, I often advise them to avoid complicated radiant floor heating systems that need continuous pumps and boilers

(they are not good for occasionally-occupied buildings anyway), to skip central furnaces with continuous fans and powered thermostats (they just make noise and blow dust around), and to avoid fan forced ventilation/heat exchanger systems (open your windows). I recommend instantaneous gas hot water heaters (you don't have to dump the hot water when you leave), gas refrigerators, gas cooking stoves (without pilots or glow bars), back-up gas direct vent wall heaters (no electricity or fans required), and real heat-producing wood burning stoves and masonry heaters.

My favorite lighting system uses 12 volt DC LED light clusters built into custom light fixtures (extremely energy efficient and they last practically forever). I recommend 12 VDC radios, televisions, and music systems (sub-woofers and VCRs included). Yes, I know, appliances are harder to find, wire loss is greater, and there are some things like computers and satellite TV systems that want 115 VAC (a portable inverter works just fine).

Many of these suggestions would test the standard construction building code, and they certainly would not make the electrical, HVAC, and plumbing contractors that are trying to sell large, expensive systems happy. I look at small, efficient 12 VDC systems as being very similar to those installed in sailboats and yachts, and they deserve an intelligently written code (an article correlating 12 VDC systems to the existing *NEC* would be great).

So my question is, why not a straight 12 volt DC system powered directly off the batteries? Skip the inverters! Skip all the redundancy, over-design, and complication required by the *NEC.* I am not saying omit safety features. I am saying be conservative, and be efficient! What have I missed? Sincerely, Paul A. Meier, Cedarburg, WI Paul@wildernessarchitecture.com

Hi Paul, You make many good points. I understand and agree with your mindset and concern. I started out in RE with a DC system, and still run much of my household on DC (primarily 24 V). You are absolutely right that it is more efficient. And it's very appropriate for cabin, boat, and RV systems, as well as for "third world" systems. If you know the advantages and drawbacks, and choose to use DC—great.

But even though I love DC, I continue to counsel people designing full house systems to go primarily or even totally AC. The fact is that we live in an AC world. I want RE use to be widespread and mainstream, not an oddball backwater. Popularizing RE means making it conventional, easy, and available. Modern inverters, while they are expensive and do rob you of a portion of your energy, make RE systems work for anyone, not just homebrewers or those willing to do the legwork to set up and use DC systems.

I applaud what you are doing, and I think that if everyone approached energy use as you do, we would be in much better shape. But I want RE to work for the masses, and I think they need to choose it in their own way, without us imposing our values on them. For most people, that means AC systems. Thanks for the inspiration, and keep up the good work. Ian Woofenden

Simple Opinion

My wife and I recently bought the June/July issue of *Home Power* magazine. Together we are doing a lot of research before we begin construction of a new home. Discovering this magazine in a bookstore on a recent trip to Dallas, we imagined that we had discovered a boon of valuable resource material and (naively) intelligent like-minded people.

Frankly, I am a little disappointed. As a resource for manufacturers and technological ideas, it is very good. Quite wonderful actually, and we thank you. Yet, after thorough reading, the editorials and general commentary found within left us both wondering about the people involved. I have to ask, what purpose does it serve to bash government and politics when the actual cost of alternative energy systems is beyond the reach of most people?

It seems to us that the people of California voted themselves into this present situation, and blaming the federal government, the California government, or "big business profit interests" simply sounds irresponsible and childish. Californians have legislated themselves into a corner that they can't get themselves out of and somehow expect government to get them out of it. It makes us wonder if anyone in that state has any idea of what has actually happened. The funniest part is, there are so many laws about what cannot be done in California that a new power generating facility is actually being built in Mexico just for California! If that isn't the height of hypocrisy!

Social elitism, political correctness, and draining state and federal tax bases by way of incentives just is not the answer. Come on now, someone there had to have gone to school! Affordability is the key! If serious home energy systems were more affordable, more and more people would be using them.

The wrong people are being focused on by you folks. Why not lobby the industries that manufacture solar cells to lower prices? Hey! There's an idea! Ask yourself why it costs twenty to fifty thousand dollars to make a single family home virtually independent from the main power grid. Then ask yourself again why we are all in the situation that we are in, California today, the rest of America tomorrow. Just think about it is all I'm saying. Look at it like this, why is there a TV set in every house in America? Not because the average American is so wealthy. Just look at the national average annual income! It's because they are affordable!

To our way of thinking, it is pretty simple. Henry Ford didn't put a car into so many garages by placing them financially out of reach to the average person. So, I've gone to college and figured this out. I'm sure that the majority of you are better educated than I am. I think you are blaming the wrong people. The voting public (shamefully the non-voting too) have to be held responsible for the California situation, and manufacturers of renewable energy systems have to be made to realize that real profits can be made by lowering prices dramatically and greatly increasing their volume of sales. Anyway, that's my unsolicited opinion. Mark Robert bulletweight@hotmail.com

Hello Mark, Thanks for your opinion. You are right, affordability is definitely a major goal, but it may not be as easy as you think. Henry Ford already knew that the demand was there before he committed to the mass production that lowered prices. Additionally, he did not have to buck corporate power that fought him tooth and nail.

In the case of home-scale renewable energy, the corporations and their government puppets have spent a lot of money and time pursuing a fossil fuel-based economy, and fighting renewable energy as an alternative. We are just now beginning to overcome the '80s corporate mantra of "solar doesn't work." Because of lack of corporate and government support (actually, efforts to defeat *), the movement for RE has been slowly building from the ground up.*

You can thank a relative handful of citizen pioneers on the cutting edge of energy supply for the prices and sophistication of equipment that we do have. If the RE equipment manufacturers were suddenly to discover that demand for modules and other equipment would instantaneously increase, you can bet that production would go up to the point that prices would come down substantially.

As for your assertion that Californians only have themselves to blame, anybody that believes voters are in control of their political "representation" is naive. The political commentary is in our magazine because we hope for changes, and mainstream media won't give the straight scoop to the public. Mexican power plants may be built in Mexico, but the reason is not that California needs the power or that the state laws discourage it. The reason is that Mexican plants can make the electricity cheaper than U.S. plants because of lack of pollution controls in that country. For that, you can thank corporate influence of the Clinton administration and their North American Free Trade Agreement (NAFTA). Michael Welch

Hi Mark, I'll just add a few thoughts to the good things Michael had to say. First of all, the Home Power *crew includes people of various political mindsets, though we are all concerned about the energy choices that people and governments make. While Michael and I don't necessarily vote for the same people, we both agree that government is certainly a significant part of the energy problem. I am not in favor of government support for renewables. I think the best thing governments could do would be to stop supporting nonrenewables, and to hold utilities responsible for* all *the effects of their electricity generation.*

To my mind, the key point is that governments for years have subsidized dirty energy. This leads to people, including you, believing that solar technology is "expensive." The full cost of your energy use includes direct government subsidies, environmental costs, war costs, health costs, etc. If you and your neighbors saw this full cost on your utility bills, you would be running *to the closest renewable energy supplier to buy the gear, at today's prices.*

You grossly oversimplify the subject when you suggest that manufacturers should simply lower prices. Anyone in business can tell you that prices are not at the whim of the company owners, but determined by manufacturing and business costs, supply, and demand. As Michael noted, when the demand for renewable energy technology increases, the price will come down. The two things we can do to help this happen are to speak out against dirty energy subsidies and socialized costs, and buy renewable energy technology now. Ian Woofenden

Welding Cable Response

Dear Editor, In response to Drake Chamberlain's article on welding cable in *HP84,* I offer the following: Article 90-5 of the 1999 *National Electrical Code (NEC)* explains the difference between required and permissive language in the code. When the word "permitted" is used in the code, it means that the requirement is optional. When the word "shall" is used without association of the word "permitted," the requirement is mandatory.

Article 690-74 concerns the use of battery cables. It is worded with permissive language so that the installer may (at his or her option) use the flexible cables (sizes #2/0 and larger) identified in Article 400 for battery interconnection cables. Appropriate single conductor cables might be types SC or W. There is no mandatory requirement that these cables be used, and if they are used, they must be terminated in the near vicinity of the batteries and connected with one of the standard wiring methods described in Chapter 3 of the *NEC.*

This permitted use of flexible cables was added to Article 690 of the *NEC* because in the larger sizes, standard, stranded building cables are very stiff and in some cases were deforming the lead terminals on smaller batteries.

If Chapter 3 flexible cables are desired, flexible conductors with numerous fine strands are available in types RHW, THW, and others. PV distributors carry these products.

Some inspectors object to the use of welding cables (even listed ones) as battery interconnection cables because they do not appear in Chapter 3, Wiring Methods and Materials, where all of the allowable types of cables are listed along with the approved wiring methods. Welding cables are also not listed in Article 400, Flexible Cords and Cables. Welding cables are only mentioned in Article 630, Electric Welders, and then only for attachment to the secondaries of electric welders. John C. Wiles • 505-646-6105
Fax: 505-646-3841 • jwiles@nmsu.edu

Move Up the Chain of Command
Dear Mr. and Mrs. Graveldinger, While I respect Mr. Woofenden's and Mr. Welch's responses ("Civic Irresponsibility," *HP84*, page 138), I think it unlikely that you will get anywhere with the anti-property rights leftists running your town, so I will offer an alternative approach. Sometimes, it really is appropriate to use a hammer to kill a fly.

You are incredibly lucky, in that your U.S. Representative is Vernon Ehlers. Not only is he a Republican (which is a point you will be using), he is chairman of the House Science Environmental-Technology subcommittee and a member of the Science-Energy subcommittee. He is also very big on helping his constituents in their dealings with various government agencies.

Contact his office (start at www.house.gov/ehlers), and ask to make an appointment to meet with his chief of staff during the upcoming August break. As a constituent, this shouldn't be all that much of a problem. They will ask for information beforehand. Send them a detailed letter explaining what your problem is. Tell them that what you are urgently seeking is a ruling from either the U.S. Department of Energy or the EPA that overrules all non-safety related local zoning as regards renewable energy installations (the zoning board has already made it clear this is an appearance issue, not a safety issue). Point out that such a ruling would be in support of President Bush's executive order on energy conservation, as well as prior executive orders issued by President Clinton and others. We can't very well have a million solar roofs if we can't put up the panels.

The precedent for a ruling such as this lies with the Federal Communications Commission, and their ruling entitled PRB-1, which strikes down all the (non-safety) local zoning rules against antennas for amateur radio operators. So they would not be breaking new ground, merely applying the weight of the federal government in helping protect your rights as property owners, as you assist the country with its current energy problems.

With a little luck, the Congressman (a Republican) can get the administration (which is Republican) to take up this issue. Especially given the committees this Congressman is involved with.

If the Congressman's office is not helpful (but you have to give them a chance first, and keep in mind that if the DOE or EPA decides to help, it will take anywhere from 90 to 180 days to make it official), contact the local media, tell them the whole sad story, and point out the failure of your Congressman to help. Being a Republican, the media will be delighted to skewer him and the administration if he doesn't come through. The media will probably be less helpful with the local politicians, whom they will likely be supportive of, although if you are lucky and there is a feud going on between the press and the local politicians, feel free to take advantage of that as well.

The key thing to remember is that so long as you are working within the system, nothing you do is wrong. It may seem dirty, rotten, and underhanded, but that *is* the system. Use it. It may be that the threat of federal action will be enough to get your local zoning board to issue a variance, in the hopes that everything stops there—better for them if they capitulate now rather than lose all their authority over this issue. Better for society if all zoning boards are brought to heel, however...

You didn't mention it in the letter, but did you get a building permit? If not, it is likely that the person at the zoning board will deny ever saying "go ahead." This should serve as a reminder to everyone who is pushing the envelope in this area—everything must be done in writing, with certified letters and return receipts. You can't trust city hall. (The same, by the way, holds for traffic tickets—certified mail, return receipt.) Best of luck. I look forward to hearing of a successful outcome in a future issue. Sincerely, Tom Frank, Middletown, RI
taf@wiredwizard.com

Consequences of Our Dirty Energy Addiction
Dear Dennis and Beth Graveldinger, I read your letter in Home Power's August/September issue. I was appalled at the Kentwood Zoning Board's response to your solar project. I live in West Virginia, where coal mining is ruining our land and water. After my experience in the Ohio coal fields, I am learning all I can about renewable energy, powering down, and planning to install a solar energy system in the near future.

I have postcards entitled "Clean Energy?" depicting mountain range removal in West Virginia. I would be happy to send you a few to distribute to your zoning board. West Virginia is counting on folks like you all over the country who realize the horrors of fossil fuels, and are willing to forge ahead into renewables.

We must turn to alternatives. I wouldn't mind having a wind turbine in my own yard if it would mean keeping some poor farmer from being coal mined. People who think solar panels are ugly have no idea what coal mining looks like. They need a lot of education. Shall I send you water from coal waste ponds for the pitcher on their meeting table?

Many folks concerned about global warming and climate change are aware of the effect burning fossil fuels has on God's creation—our environment, our wildlife, our climate, and our lungs. Evidence is gathering that mankind is changing everything from the very weather we depend on to the health of our children. My own introduction to this issue was through witnessing the coal extraction process.

In 1997, I was involved in organizing in Belmont County, Ohio, to save Ohio's last unglaciated, deciduous, virgin forest, and one of God's precious creations, Dysart Woods, from a coal-mining permit. I became known to the local farmers in the area. I was invited to their homes to see the actual damage done by a coal extraction technique called long-wall mining. This is a method of total extraction that immediately subsides everything above the coal seam (the overburden). I was shocked at what I witnessed.

The people who had been recently undermined suffered more damage than I could have imagined. There were cracks in the walls so wide that in some cases you could see the sky through them. Everything built of brick or cement (walkways, basement walls and floors, foundations, chimneys, fireplaces) was popping and crumbling. Windows were coming out of their frames, and in some cases the septic tanks had backed up into the basement. In one case, the basement walls folded in and the home was in a state of collapse (video available).

In every case that I saw, the natural water on the land had disappeared. The owners (and all local wildlife) had lost their wells, streams, ponds, and springs. This represented a dewatering of many thousands of acres. Approximately half of Belmont County has been, or soon will be, dewatered due to mining practices. Picture 90 percent of the natural water lost (according even to the mining permits on record) to surface dwellers. What can wildlife drink? Where do frogs live after the long-wall? What do farmers do?

And how does the government justify approval of this dewatering while at the same time encouraging the population at large to *conserve* fresh water? It seems ludicrous to try to save a gallon per flush when each undermined farm might have lost as much as 100 gallons per minute.

It has been my experience that the coal companies interpret assistance from outsiders to these mined people as confrontational activities. Any help given to these people are characterized as acts "unfriendly" to the coal company. The general populace (including all local businesses), consciously or not, seems to be in awe or frightened of the coal company. Even local attorneys say they won't take a case against the coal company, if they "expect to keep practicing in this county."

The county and state disaster agencies have agreed that people affected by the mining are facing a true disaster, but the agency funding is earmarked for natural disaster and "accidental" disasters. Unfortunately, what the land, the wildlife, and the people experience during mining is manmade, deliberate, and approved by the local, state, and federal government, so the agencies are unable to offer help.

As a health caregiver, I have been trained to the patterns of psycho-trauma-dynamics following a tragic event—spinal cord injuries, traumatic brain injuries, etc. I was struck by the similarities I found in people who have been mined. There is shock, denial, hysteria, confusion, much anger, and then deep sadness, frequently followed by isolation and deep depression. These are the emotional states they are experiencing just at the very moment when they need to be at their cognitive best in order to keep track of their damage, who they contacted about their damage, and the kind of response received. If they hope to get any reimbursement from the coal company (usually not for several years), they must also keep accurate records of everything that transpires. The farmers are stunned by the enormity of the sacrifice they have been forced to make for our country's energy source. The land that they loved and their livelihood is ruined.

Dr. Gordon Lewis of Carnegie Mellon University in Pittsburgh has likened this psychological state to the post-traumatic stress syndrome of the Vietnam War. Is it any wonder why the folks in Appalachia seem depressed?

American demand for "cheap" energy is at the root of all this. All this heartache and devastation to God's creation and the farming community and farm owners comes, in part, from our careless consumption of electricity that, I have come to realize, we by and large squander.

Since I have been aware of this situation, and realized the moral implications, I have reduced my use of electricity considerably. I began my journey as a 600 kilowatt-hour per month user and so far have pared down to a 230 kilowatt-hour user in preparation for renewable energy.

Know your kilowatt-hour usage printed on your bill each month! It is a measurement of your awareness and your commitment to save our planet, God's creation, and our mined neighbors.

Let me know what you need to make your point, and bless you for all the things you are doing to advocate renewables. Dianne Burnham, The Wheeling Environmentalists Interfaith Global Climate Change Campaign

The Need for a Federal Net Metering Law

Richard Perez

Renewable energy (RE) is derived from solar, wind, small-scale hydroelectric, and sustainable biomass generation sources. Net metering laws allow RE producers to interconnect with utility grids, and to place their surplus RE on the grid. In essence, these laws allow RE producers to spin their electric meters backwards and receive a credit for the energy they place on the grid.

With net metering, the RE we place on grid is credited to our utility accounts at retail electric power rates. The utility credits us at the same value they charge us—retail energy cost. Net metering is best characterized as a demand side management tool. Like purchasing energy efficient appliances, RE generation enables consumers to reduce their grid-supplied electrical energy consumption and their utility bill.

Net Metering Laws Benefit Everyone

The benefits of both renewable energy and net metering are fairly obvious for owners of small RE systems. The system owners get high quality, uninterruptible, and environmentally clean electricity. They also may get a large reduction in their monthly utility bill, even down to zero in some cases. And they get to share their surplus RE with their neighbors.

The utility also benefits by net metering RE resources. Perhaps the most obvious benefit to the utility is immediate load reduction—a relief to overburdened utility grids. The utility gains a small distributed generator, without having to spend a cent of its own capital. The user is paying for all the RE equipment, and the energy is supplied free by nature. Utilities also have the option of selling renewably generated electricity to consumers at premium rates via optional "green billing" programs.

The utility gets the finest and cleanest form of electric power, without having to invest anything in generating it. Since most net metering is done with solar electricity, the utility's load is reduced during peak consumption hours—during the day. Because the RE is locally produced and consumed, it reduces the loading of the utility's power distribution system, and lessens the need for more expensive power lines.

Society as a whole also benefits from net metering small RE systems. Each of these systems is a non-centralized generating source that bolsters the reliability and power quality of the nation's electrical grids. The energy inputs to these RE systems are sunshine, wind, and water—all locally supplied and free fuel sources.

RE reduces U.S. dependence on imported energy. The state of Montana reportedly has enough wind resource to power the entire nation. The sunlight falling in the southwestern states has enough energy to power the nation. With natural, free resources such as these, it makes little sense to import our energy from overseas. Developing domestic RE resources will make the United States a stronger, more self-sufficient nation. Developing our RE resources will make it unnecessary for us to go to war to secure our energy supplies. Developing distributed renewable energy just makes good economic and political sense.

Since renewable energy is produced using sunshine, wind, and water, it has minimal environmental pollution. A single 1,000 watt solar electric array will displace one metric ton (2,200 pounds) of carbon dioxide each year. These small RE systems can help to clean up our environment.

State Net Metering Laws

The benefits of net metering have been realized in many states. Currently, 34 states have passed state net metering laws, and 4 more are considering them. The following states have net metering laws: Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Minnesota, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Vermont, Virginia, Washington, Wisconsin, and Wyoming. Nebraska, Kansas, North Carolina, and the District of Columbia have pending legislation.

While all these state laws allow interconnection with the utility grid, each law is different. In some states, if a

system produces more energy than it consumes and shows a yearly surplus, the system's owner receives payment for this surplus at avoided generating cost, usually around 2 cents per kilowatt-hour. In other states, any yearly energy surplus is donated to the utility. In some areas, a premium is paid to the system owner for surplus RE, and the local utility resells it as "green power."

Technical interconnection standards also vary from state to state. Net metering periods vary from a month in some states to a year in others. Maximum system size varies from 10 KW to no limit. If we had a federal net metering law, all of these details could become standardized.

A Federal Net Metering Law

If the U.S. were to adopt a national net metering law, it would join Japan, Germany, and Switzerland—countries that already have such laws in place. These are nations that are converting to clean renewable energy many times faster than the U.S. They are not experiencing energy shortages and blackouts.

A federal law will streamline the net metering process and encourage more new RE systems. Actually connecting a net metered system to the grid can be legally difficult. Each state and each utility have different technical standards for the equipment, especially the safety and metering gear. A federal law will standardize this. The equipment used in RE systems is UL listed for safety, like every other home appliance. In addition, utility approved inverters that interface RE generation with the utility grid have received IEEE certification.

A federal law will also standardize the net metering period in all states. This would help financially with the seasonally variable RE resources of sun, wind, and water. A federal law will standardize system size, preferably at levels much higher than the 10 KW and 25 KW limits now common in most state laws. California recently raised its limit on net metered system size from 10 KW to 1,000 KW, in light of their recent energy crisis.

A federal net metering law could take the very best points from the various state laws. Some of these state laws have been in effect since the early 1980s, and we've learned much from their application. Here are some of the features we need in a federal net metering law.

1. It should apply to all utilities regardless of type—investor owned utilities, municipal utilities, and rural electric cooperatives.
2. Eligible fuels should be solar, wind, hydro, and sustainable biomass.
3. All utility customer classes (residential, commercial, agricultural, and industrial) should be eligible to net meter.
4. There should be no limit on system size. The U.S. needs all the energy it can get, especially clean, sustainable energy.
5. The net metered time period should be one year.
6. The net excess generation produced by the system during the net metered period should be credited to the system's owner at a minimum of the retail price and ideally at a higher than retail price. This energy could then be resold to utility customers at a premium price through optional utility "green power" programs.
7. Net metering should be allowed in addition to other utility programs, such as time of use metering.
8. Utilities not complying with the federal net metering law should be denied federal subsidies.

Considering the stressed-out state of the U.S. electrical grid, distributed RE production offers some immediate relief. Considering the mature nature of small-scale RE systems, their production can be relied on—it's as dependable as the sunrise. Considering the snail's pace at which utilities are developing RE resources, having RE net metered systems that are privately funded will help green-up utility power more quickly. Considering the net metering experiences in other countries and in the majority of the states in the U.S., isn't it time we had a federal net metering law?

Access

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Q&A

Remote Cell Phone Antennas

Dear Mr. Greenslate, I recently read your article in *HP83,* which I enjoyed. We have a cabin in the Black Hills in Wyoming and are off the grid. We use RE, and have a spring for water, etc. The one missing feature at our place is telephone service. Our house is in a valley, but if I go about a half mile down the road and up on a ridge, I can get service through my AT&T cell phone.

With great interest, I read that you have been able to use your phone with a Yagi antenna. I contacted AT&T and they gave me their accessories phone number. They had no such product. I checked the Internet and Radio Shack, all to no avail.

I would really appreciate it if you could give me some more info, such as where you got your antenna, if there is some sort of special connection, cost, etc. Sincerely, John Green, Austin, Texas • gogreen@austin.rr.com

Hi John, Our system is a Nokia 2160 cell phone set into a Nokia CARK-11 car installation kit. I have fastened the holder and handset to the wall in the livingroom, and connected it to our original 12 V PV system. I discarded the auto antenna and connected an 800 MHz Yagi antenna in its place. The Yagi is model YA-800 manufactured by Larson Antenna Technologies. It took 20 feet of coax cable with a threaded connector at the antenna end and a miniature connector at the CARK-11 end. You will need to have the cable made up if you don't have a crimper and soldering iron.

Because of the problems we had experienced with weak signals, we paid a professional, Chris Nelson, to come out and wave the antenna around to locate the best installation point. It turned out to be the same location we had been using for our other radios and phones. It appears in the article in the photo on page 31, above the M-77 panel.

AT&T has been at us recently to change our phone to a newer model. But they said it would not be compatible with our existing kit, and they had no suggestion as to how to get the same service we now get with their new model. This may be part of your difficulty. One of the AT&T salespeople said they had a system in development that would meet our needs, but it wouldn't be available for two or three years.

Cell Phone Yagi Antenna Costs

Item	*Cost (US$)*
Nokia CARK-11 car installation kit	$209
Larson Antenna Tech. YA6-800 antenna	80
Site selection services	50
Cable and connectors	17
Total	$356

The only shortcomings we have experienced with the Yagi is an occasional gradually fading signal coming in, and it is extremely directional. Most cell phone antennas are multidirectional, since the signal can come from anywhere on the hand-off. If you install the system, you may not be able to make or receive calls unless the phone is in the CARK-11 holder. It is kind of like a rifle shot compared to a shotgun. The fading seems to be on our end only, since the people we are speaking with don't notice it. It is possible that it has to do with the state of charge of the batteries.

We have found that leaving the phone plugged into the kit kills the battery life, especially NiCds. NiMH batteries last longer, but still can't take constant charging. So we've found a spot in the kitchen window where the phone will ring in. We then grab it and run to the kit holder before answering, sometimes unsuccessfully. The missed call feature helps here, too. I haven't had any luck finding a lead-acid replacement battery, or a method of connecting directly to the phone circuit with our PV system.

You should also know that the Nokia 2160 has a signal strength screen built in. It appears on the 01 screen at the top line. The minus number on the left top side has a reverse correlation with the signal strength. The smaller the minus number, the stronger the signal. If the number is -105 or greater, forget it. When we first installed the Yagi, we had -79, which gave us a full strength signal indication. We now have from -87 to -93 when camping, and it will drop to -79 in use. Chris Nelson told us that the phone company can re-aim their antenna, which may account for the change. It seems they do this in response to complaints from roaming users.

I hope this gives you some help. I would suggest you try to find a Ham radio wrench in your area if you can. My experience with the service center people has not been very informative. The same was true of the people I talked to at Radio Shack. They are very interested in making the sale, but it's stonewall from there. Good luck, and write if you feel we can be of any further help, or if you find a better way. Will Greenslate, PO Box 312, Mosier, OR 97040.

Computer Loads Answer

In response to your *Q&A* on computer loads in *HP84,* page 153, we have been delighted to (finally) change this year to liquid crystal flat screens at about 25 watts

instead of the 75 of the CRT variety (plus the benefits of no x-ray emissions). I got one analog Acer Open that was a true plug-and-play set-up but is slightly fuzzy, and one Toshiba digital model PV2007U that is sharper than anything. The Toshiba came with a driver card that required several days of phone miracles to get the correct info and software to get it going.

With discounts and a Toshiba coupon, this change cost me only about US$450 each, and they are starting to show up in Staples stores and many catalogs. These monitors use about 25 watts, which is too high, but a great difference in a 14 hour day of three computers.

Also remember with Windows you can change settings so the machine goes to “low power standby” or “shut off monitor” after so many minutes. “Low power standby” blanks the CRT screen, but still draws all 75 watts, while “shut off monitor” really drops the power to about 10 watts, depending on the monitor. In my somewhat outdated experience with Windows 95 and 98, power down is not checked off when first fired up even in energy star versions. You must right click on the desktop and go to properties and to the screen saver tab. Steve Willey, Backwoods Solar Electric, Sandpoint, Idaho • steve@backwoodssolar.com

Hello Steve. The new LCD computer monitors are real energy savers. They are still sort of expensive in the bigger display sizes—19 inches or larger. I’m lusting after the Apple 22 inch LCD, but at US$2,500, it’s too expensive. The only real technical objection I have to the LCD computer monitors is that their color is not as true to life or as high quality as the best CRTs. This is only a problem if you are using the display to process photos or art for color printing. Richard Perez

PV Output Too Low

Dear Richard, I am experiencing a situation that I don’t partially, much less fully, understand. I have six 120 watt at 7 amp PV panels on a rack in the sun. I’ve adjusted the angle for the season on a monthly basis. They are wired into three series strings and then joined to a #4 cable for the 20 foot run to the charge controller. I am using #10 for the array interconnects with no lead longer than 8 feet.

At high noon on a cloudless day in Phoenix with an outside temperature of 108°F, I was receiving a roaring 3 amps according to my Cruising meter. I figure that in a utopian situation, I should be getting at least 15 amps. Am I possibly reading my meter wrong, or do I not understand its function? Thanks for your time. Carl Glassmeyer • Usnrr@fastq.com

Hello Carl, Your instrumentation is probably working. First make sure that the battery is not fully charged. If your array is connected to a full battery, the PV controller could be regulating. If that’s not what’s up, the problem is probably that your PV modules are hot. This causes the PVs’ output voltage to decrease. When PVs are hot (above 50°C or 135°F), their voltage and hence their power output decreases. This loss can be up to 30 percent for some modules.

Add this condition to a rising battery voltage (since the battery is being recharged), and you have a very small voltage differential between the battery and the PVs. This causes a radical decrease in current to the battery. A quick test for this condition is to hose down the modules with cool water and quickly run inside and check the ammeter. Try this when the batteries are discharged enough to allow maximum current. I’ll bet you see a large increase in output. Richard Perez

Writing for *Home Power* magazine

Home Power is a user's technical journal. We specialize in hands-on, practical information about small-scale renewable energy systems. We try to present technical material in an easy to understand and easy to use format. Here are some guidelines for getting your renewable energy (RE) experiences printed in *Home Power.*

Informational Content

Please include all the details! Be specific! We are more interested in specific information than in general information. Write from your direct experience—*Home Power* is hands-on! Articles must be detailed enough that our readers can actually use the information. Name names, and give us actual numbers, product names, and sources.

If you are writing about someone else's system or project, we require a written release from the owner or other principal before we can consider printing the article.

Article Style and Length

Home Power articles can be between 350 and 5,000 words. Length depends on what you have to say. Say it in as few words as possible.

We prefer simple declarative sentences that are short (fewer than twenty words) and to the point. We like the generous use of subheadings to organize the information. We highly recommend writing from within an outline. Check out articles printed in *Home Power.* After you've studied a few, you will get a feeling for our style.

We edit all articles for accuracy, length, content, organization, and basic English. You can help by keeping your sentences short, simple, and to the point. Our editing crew will make your text shine.

Photographs

We can work from any photographic print, slide, or negative. We prefer 4 by 6 inch color prints with no fingerprints or scratches. Do not write on the back of your photographs, since the ink can transfer to the front of the next photo. Please provide a caption and photo credit for each photo. Include some vertical format photos—you might even find your system on *HP's* cover. People are nice in photos; a fuse box is only so interesting, even to solar nerds.

Digital photos should be at least 280 pixels per inch (ppi) at the final printed size. This means that a column width photo should be 1,000 pixels wide or more. A full page width photo should be at least 2,300 pixels wide. Basically, set your digital camera at its highest resolution, and crop thoughtfully. We prefer Photoshop files, but we can handle the following formats in descending order of preference—EPS, TIFF, and JPEG.

Art, Schematics, & Tables

System articles must contain a schematic drawing showing all wiring. Our art department can make gorgeous diagrams, charts, and schematics from your rough sketches. If you want to submit a computer file of a schematic or other line art, please call or email us first.

For system articles, we require a load table listing all loads, with wattage and run time. We also require an itemized cost table listing each system component and its cost. We prefer to have the tables come to us in Excel format. But we can use them from any word processor or spreadsheet format if they are saved as "text only," with tabs as the delimiter between cells.

Computer Talk

We can take text from most word processors. Save all word processor files in "TEXT" or "ASCII TEXT" format. This means removing all word processor formatting and graphics. Use the "Save As Text" option in your word processor.

If you want to send files larger than 5 MB (such as digital photos), use removable media and snail mail it to us. We can read ZIP disks (either Mac or IBM) and CD-ROMs. You can also FTP your large files to us at ftp.homepower.com, to the "incoming" folder. Please let ben.root@homepower.com know after you have sent us files via FTP.

Putting it All Together

We get many more articles submitted than we can print. The most useful, specific, organized, and complete get published first. Here are the basic components of a great *Home Power* article:

- Clearly written, well organized, and complete text, with a strong introductory paragraph, subheads for each major section, and a strong closing paragraph.
- Photos (plenty) with clear captions.
- Cost table.
- Load Table.
- Other tables, charts, and diagrams as appropriate.
- System schematic.
- Complete Access information for author, installers, consultants, suppliers, and manufacturers.

Have any questions? Give us a call Monday through Friday from 9 to 5 Pacific and ask. Or send e-mail. This saves everyone's time. We hope to see your RE project in *Home Power* soon!

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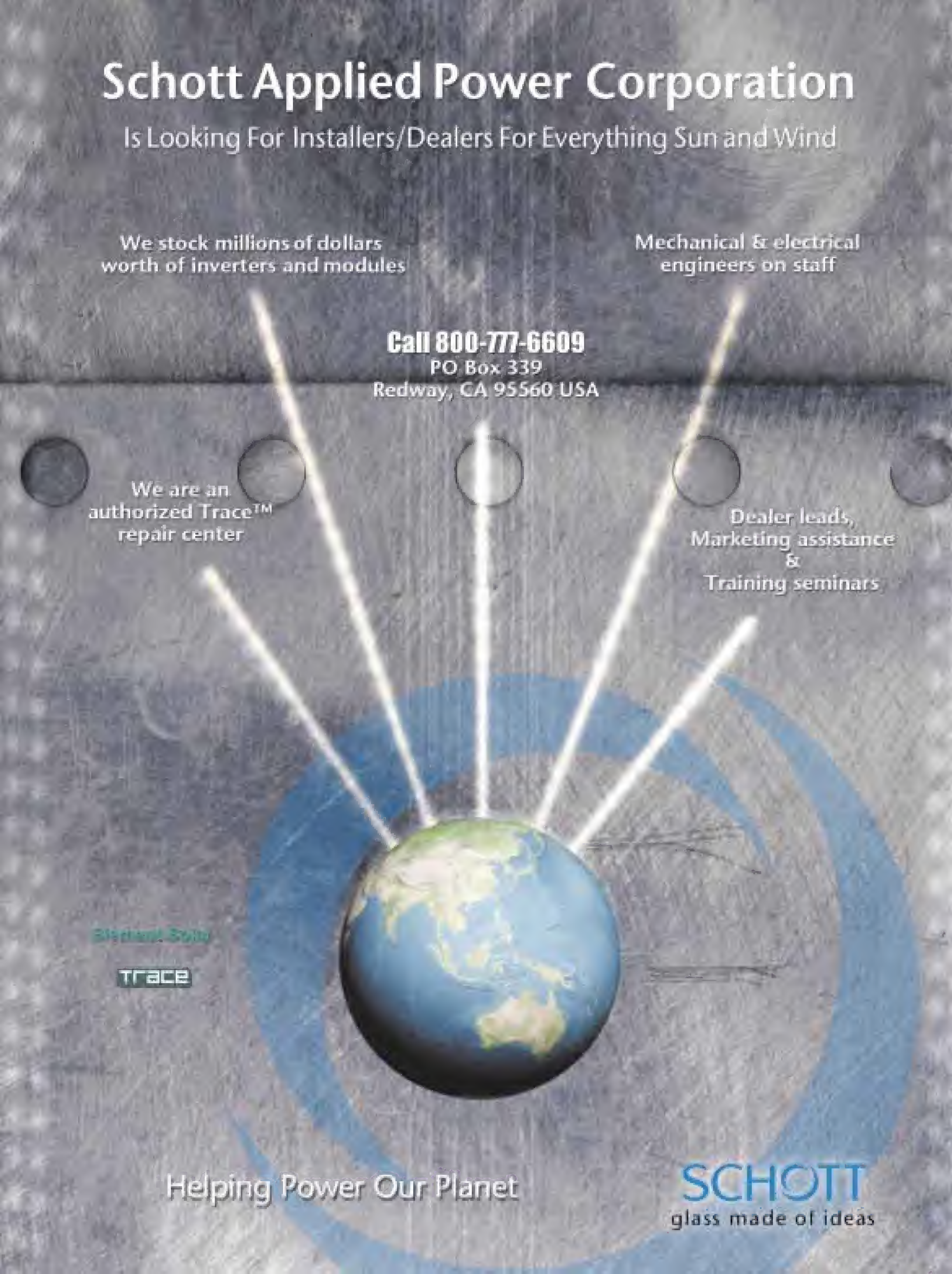
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❑ All electricity
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(continued on reverse)

I now use, or plan to use in the future, the following renewable energy equipment (check all that apply):

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❑	❑	Wind generator	❑	❑	Thermoelectric generator
❑	❑	Hydroelectric generator	❑	❑	Solar oven or cooker
❑	❑	Battery charger	❑	❑	Solar water heater
❑	❑	Instrumentation	❑	❑	Wood-fired water heater
❑	❑	Batteries	❑	❑	Solar space heating system
❑	❑	Inverter	❑	❑	Hydrogen cells (electrolyzers)
❑	❑	Controls	❑	❑	Fuel cells
❑	❑	PV tracker	❑	❑	RE-powered water pump
❑	❑	Engine/generator	❑	❑	Electric vehicle

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